Summarizing Responses to Corps District Requests for WRAP Scientific and Technical Assistance

by Robert Lazor,[1] Janean Shirley,[1] Virginia Dickerson[2]

PURPOSE: This technical note provides U.S. Army Corps of Engineer (USACE) users, particularly in regulatory functions, with significant case studies of Wetlands Regulatory Assistance Program (WRAP) responses to requests for scientific and technical assistance conducted for USACE Districts and Divisions by the U.S. Army Engineer Research and Development Center (ERDC).

BACKGROUND: Past WRAP projects contain technical information that may have applicability outside the specific project site. ERDC responses to District requests for assistance under the WRAP Program may be of interest to other regulatory branches within the Corps and represent a "lessons learned" approach. Approximately 30 to 40 WRAP responses are prepared annually addressing a wide range of Section 404 Clean Water Act issues including, but not limited to, delineation, mitigation, threatened and endangered species, habitat concerns, functional assessment, legal (scientific and technical), and other controversial subject areas (e.g., seagrass shading effects, special aquatic areas). However, the technology gained in preparing these WRAP responses is not currently transferred to other users within the Corps.

APPROACH: The investigators examined numerous past WRAP responses (FY92-FY02) for the following selection criteria:

1. Specificity—delineation, mitigation, functional assessment, etc.
2. Location or geographic range.
3. Wetland type (riverine, coastal, fringe)
4. Transferability.

Following examination, the investigators selected the following documents, corresponding to the five areas of wetland subject matter:

1. **Delineation**, "Wetland Determination at Kinkead Avenue and Meadow Drive, North Tonawanda, NY," Buffalo District, 2000, 16 pp.
2. **Mitigation (Basic Fish Processes)**, "WRAP Request for Assistance in Investigating the Swimming Stamina of the Topeka Shiner," Kansas City District, 1998, 14 pp.
3. **Threatened and Endangered Species**, "Dredging Permit for Mobley Construction Company in the White River, Arkansas: Paddlefish Spawning Habitat in the Exclusion Zone," Memphis District, 2000 and 2002, 60 pp.

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[1] U.S. Army Engineer Research and Development Center, Vicksburg, MS.
[2] DynCorp, Vicksburg, MS.

4. **Special Aquatic Areas (Seagrass Shading, Over-water Structures)**, "Recommendations to Minimize Potential Impacts to Seagrasses from Single-family Residential Dock Structures," Seattle District, 2002, 28 pp.
5. **Functional Assessment**, "Assessment of Potential Wetland Impacts Due to Proposed Realignment of Virginia Route 17, Southern Chesapeake, Virginia," Norfolk District, 2001, 26 pp.

Documents that resulted from these projects are attached.

BENEFITS: The attached documents provide Corps users involved in Section 404 (Clean Water Act) regulatory activities with access to information regarding WRAP studies previously conducted. Users may be able to consider the application of these projects to work that is currently being done or projects that are being planned and/or executed.

POINTS OF CONTACT: For additional information, contact the following individuals at the U.S. Army Engineer Research and Development Center for the particular wetland subject matter areas designated below:

Delineation:
Dr. James Wakeley (601-634-3702, James.S.Wakeley@erdc.usace.army.mil)
Dr. Barbara Kleiss (601-634-4674, Barbara.A.Kleiss@erdc.usace.army.mil)

Mitigation (Basic Fish Processes):
Dr. Jan Hoover (601-634-3996, Jan.J.Hoover@erdc.usace.army.mil)
Dr. Jack Killgore (601-634-3397, Jack.Killgore@erdc.usace.army.mil)

Threatened and Endangered Species:
Dr. Jan Hoover (601-634-3996, Jan.J.Hoover@erdc.usace.army.mil)
Dr. Jack Killgore (601-634-3397, Jack.Killgore@erdc.usace.army.mil)

Special Aquatic Areas (Seagrass Shading, Over-water Structures):
Ms. Debra Shafer (601-634-3650, Deborah.J.Shafer@erdc.usace.army.mil)

Functional Assessment:
Dr. Ellis Clairain (601-634-3774, Ellis.J.Clairain@erdc.usace.army.mil).

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CEERD-EE-W 3 November 2000

MEMORANDUM FOR RECORD

SUBJECT: Wetland Determination at Kinkead Avenue and Meadow Drive, North Tonawanda, NY (WRAP 01-1)

At the request of the Regulatory Branch of the U. S. Army Engineer District, Buffalo, NY (the Buffalo District), I visited the undeveloped property at Kinkead Avenue and Meadow Drive, North Tonawanda, NY. The owner has proposed to develop a portion of the property near Meadow Drive. A consulting firm, Earth Dimensions, Inc., Elma, NY, performed a wetland delineation on the property in September 1999 and concluded that 3.24 acres of the approximately 18-acre tract were wetlands potentially regulated under the federal Clean Water Act, and that most of this wetland acreage was outside the portion proposed for development. However, the consultant's wetland delineation differed considerably from that performed by personnel of the NY Department of Environmental Conservation (NYDEC) pursuant to State regulations. NYDEC concluded that portions of the area proposed for development contained regulated wetlands.

Through the Wetland Regulatory Assistance Program (WRAP), the Buffalo District asked for assistance from the Environmental Laboratory of the U. S. Army Engineer Research and Development Center, Vicksburg, MS, in reconciling the different wetland determinations on the Kinkead Avenue and Meadow Drive site. During my visit to the site on 27 October 2000, I was accompanied by Dr. Barbara Kleiss, Supervisory Hydrologist with the U. S. Geological Survey, Division of Water Resources, Pearl, MS, and by Messrs. Gary Mcdannell, Harold Keppner, and Marty Crosson of the Buffalo District. We did not attempt to delineate wetland boundaries. Instead, we generally inspected areas designated as wetland and nonwetland by Earth Dimensions, Inc., sampled and recorded data at three representative sampling points (data forms are attached), and judged whether or not significant areas of wetland may have been overlooked by the consultant. We had access to the consultant's 1 February 2000 wetland delineation report and to a report dated 18 September 2000 by Steve Carlisle, Soil Scientist with the U.S.D.A. Natural Resources Conservation Service (NRCS), concerning his investigation of soils on the site. There were no obvious surveyed markers on site to determine the exact location of our sampling points. However, our point A was probably located slightly east of the consultant's mapped sampling point D-19; our point B was located roughly between the consultant's points D-7 and D-12; and our point C was located slightly north and west of the consultant's point D-5.

According to the 1987 *Corps of Engineers Wetlands Delineation Manual* (the 1987 Manual), an area is wetland if it has three essential characteristics – hydrophytic vegetation, hydric soils, and wetland hydrology. The first two are relatively easy to observe and interpret in a brief site visit because evidence of a hydrophytic plant community and hydric soils is usually present on a site year round. The third characteristic, wetland hydrology, can be problematic if wetlands are not visited during the normal wet portion of the growing season. The following sections discuss each essential wetland characteristic in relation to the Kinkead Avenue and Meadow Drive site.

Vegetation

An area has hydrophytic vegetation if more than 50% of the dominant plant species from all strata (i.e., trees, saplings/shrubs, herbs, and woody vines) are rated as obligate (OBL), facultative wetland (FACW), or facultative (FAC) on the appropriate regional version of the 1988 *National List of Plant Species that Occur in Wetlands* published by the U. S. Fish and Wildlife Service. The Kinkead Avenue and Meadow Drive site was forested and had a mostly closed canopy (expect where logged) of generally FACW and FAC trees. Dominant species on our three plots included red maple (*Acer rubrum*, FAC), pin oak (*Quercus palustris*, FACW), green ash (*Fraxinus pennsylvanica*, FACW), and cottonwood (*Populus deltoides*, FAC). The sapling/shrub stratum, when present, contained some of the same species. The herb stratum was sparse over much of the area and contained seedlings of the overstory trees in addition to sedges (*Carex* spp.), fowl manna grass (*Glyceria striata*, OBL), stout wood-reedgrass (*Cinna arundinacea*, FACW+), soft rush (*Juncus effusus*, FACW+), iris (probably blueflag, *Iris versicolor*, OBL), Virginia knotweed (*Polygonum virginianum*, FAC), and other plants. Vegetation was hydrophytic at all three sampling points and appeared to be generally hydrophytic throughout the site. Earth Dimensions, Inc., reached similar conclusions. They found hydrophytic vegetation at 20 of 22 points they sampled.

I conclude that hydrophytic vegetation is present across much of the site.

Soils

A hydric soil is defined by the National Technical Committee for Hydric Soils (NTCHS) as a soil that was formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part (Federal Register 59(133):35680-35681, July 13, 1994). Hydric soils are recognized in the field by morphological characteristics, such as soil color, that are called hydric soil indicators. Hydric soil indicators are listed in the 1987 Manual. In addition, NRCS has developed an updated list of hydric soil indicators, the *Field Indicators of Hydric Soils in the United States*, version 4.0, March 1998, which is accepted by the Corps as supplemental information in a wetland delineation.

Soils on the Kinkead Avenue and Meadow Drive site were mapped entirely as Canandaigua (Ca) series by the NRCS in the 1972 Niagara County soil survey report. Canandaigua is classified as a Mollic Endoaquept, described as poorly to very poorly drained, and listed as hydric on the Niagara County list of hydric soils.

Earth Dimensions, Inc., concluded that three soil types were actually present on the site: Canandaigua series, Niagara series, and Udorthents (areas of fill). They further determined that only the areas of Canandaigua were hydric and, therefore, could potentially be wetlands. Niagara series is described in the Niagara County soil survey as somewhat poorly drained. It is listed on the Niagara County list of hydric soils because mapping units of generally nonhydric Niagara soils are likely to contain included areas of hydric soils.

In practice, hydric soils are identified in the field by the presence of hydric soil indicators that reflect prolonged inundation or saturation during the growing season, not by the listing of the soil name on the hydric soil list. Hydric soil lists are intended as preliminary office-based information that may indicate the likelihood of hydric soils on a property. The actual presence or absence of hydric soils must be verified through on-site investigation.

At Kinkead Avenue and Meadow Drive, we found hydric soils at all three of our representative sampling points based on indicators in the 1987 Manual and indicator F3 of the NRCS list of field indicators of hydric soils. Our point A was located within the area designated by Earth Dimensions, Inc., as nonhydric Niagara soils. Point B was in the area designated as hydric Canandaigua soils by Earth Dimensions. Point C was in an area designated by Earth Dimensions as nonhydric fill (Udorthents). In addition, Steve Carlisle, NRCS Soil Scientist and experienced soil mapper in Niagara County, found hydric soils at all four of the representative sampling points he documented in his 18 September 2000 report. He concluded that all four soils were natural and not fill; all four were appropriate to the Canandaigua mapping unit shown in the soil survey; and all were hydric based on soil colors. Furthermore, he concluded that areas of fill were only "a small proportion" of the site.

Based on the evidence above, I conclude that hydric soils are more extensive on this site than was indicated by Earth Dimensions, Inc., in their wetland delineation report.

Hydrology

According to the 1987 Manual, an area has wetland hydrology if it is inundated or saturated for at least 5% of the growing season in most years. The North Tonawanda area has a growing season that, on average, starts April 14 and ends October 31, a period of 200 days (NRCS National Water and Climate Center, Portland, OR). Therefore, the critical threshold for wetland hydrology in this area is approximately 10 consecutive days. Areas that meet this criterion *and* have hydrophytic vegetation and hydric soils are wetlands under the 1987 Manual.

As Dr. Kleiss pointed out in her hydrologic evaluation of the Kinkead Avenue and Meadow Drive site (copy attached), the most appropriate time of year to evaluate the hydrology of any site in this region is early in the growing season (i.e., mid April to late May) when precipitation, snowmelt, and other sources of water exceed losses due to evapotranspiration and sites are at their wettest. Unfortunately, all of the recent evaluations of the Kinkead Avenue and Meadow Drive site have been during September and October, when the site is at its driest. During this period, direct observation of flooding, ponding, or soil saturation is very unlikely and a hydrologic evaluation must rely on indirect *indicators* of hydrology. The 1987 Manual and recent guidance memoranda from Corps Headquarters recognize features such as water marks on trees, drift lines, sediment deposits, oxidized rhizospheres, water-stained leaves, local soil survey data, and a plant community that passes the FAC-neutral test as valid indicators of wetland hydrology.

All three of the representative sampling points we examined on the Kinkead Avenue and Meadow Drive site had sufficient indicators of wetland hydrology to conclude that wetland hydrology was present, including water-stained leaves, vegetation that passed the FAC-neutral test, and local soil survey data for the Canandaigua series. The Niagara County soil survey indicates that Canandaigua soils have a high water table within 6 inches of the surface and are sometimes flooded throughout the spring.

Consultants from Earth Dimensions, Inc., examined the site in September 1999 and, as expected during the dry season, did not observe either inundation or shallow soil saturation on the site. They observed hydrology indicators at four sampling points and ultimately concluded that seven points had wetland hydrology, for reasons that were not clear on the data forms. (Earth Dimensions did not use the official Corps of Engineers wetland delineation data form and their list of wetland hydrology indicators differed.)

In addition to the official wetland hydrology indicators given in the 1987 Manual, we observed other evidence suggesting that the site has been inundated or saturated regularly in recent years, including extensive areas of bare soil that lacked herbaceous plant cover, a few areas of soil cracks and polygons that are produced when wet soils dry out, and morphological adaptations of woody plants for life in wet conditions (e.g., flared and enlarged bases on trees, enlarged lenticels or surface pores on the bases of some saplings, multiple stems).

I conclude that wetland hydrology is more extensive on this site than was indicated by Earth Dimensions, Inc., in their wetland delineation report.

Conclusions

Based on the evidence described above, I conclude that Earth Dimensions, Inc., may have significantly underestimated the extent of wetlands on the Kinkead Avenue and Meadow Drive site. Although we did not determine wetland boundaries during our 27 October 2000 site visit, our observations suggest that the wetland boundary marked by the NYDEC at the southern end of the property may be closer to the Corps' jurisdictional limits than the boundaries drawn by Earth Dimensions. If necessary, the site should be reexamined, preferably during the early part of the growing season, to establish the wetland boundary more accurately.

Of the three essential wetland characteristics given in the 1987 Manual – hydrophytic vegetation, hydric soils, and wetland hydrology – wetland hydrology is the most problematic to evaluate during a brief site visit. In seasonal wetlands, the problems are compounded when the site must be sampled during the dry season. The 1987 Manual recognizes this fact and provides added flexibility when hydrology indicators are lacking during dry-season investigations in seasonal wetlands (see Section G, Problem Areas, paragraphs 77-79). In addition, a 1995 report from the National Research Council concluded that the presence of both hydric soils and a hydrophytic plant community is strong evidence of wetland conditions in areas where hydrology has not been significantly disturbed. The Corps requires that all three essential characteristics be present to conclude that an area is wetland. However, delineators should take special care when the lack of hydrology indicators seems to be in conflict with the presence of hydric soils and hydrophytic vegetation on relatively undisturbed sites. Further analysis of the hydrology of the site may be needed to make an accurate wetland determination.

From a technical viewpoint, there are two courses of action if there is further disagreement about the extent of wetland hydrology on the Kinkead Avenue and Meadow Drive site. The first is to reexamine the site during the early part of the growing season (i.e., mid April to late May) when conditions are expected to be at their wettest. At that time, direct observations of inundation and/or soil saturation may resolve the questions. Second, installation of manual or automated surface-water and groundwater monitoring equipment would provide hard data that could be used to verify whether the wetland hydrology criterion (i.e., inundation or saturation for at least 5% of the growing season in most years) is met. The second option could require considerable planning, effort, and expense. For both courses of action, an evaluation of antecedent precipitation would be needed to determine if rainfall that year was within normal limits and not unusually excessive or droughty.

James S. Wakeley, PhD
Wetlands and Coastal Ecology Branch

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: KLYDELL WETLANDS Applicant/Owner: PROBST Investigator: WAKELEY, KLEISS, MCDANNELL, KEPPNER	Date: 10/27/00 County: NIAGARA State: NY
Do Normal Circumstances exist on the site? Yes No Is the site significantly disturbed (Atypical Situation)? Yes No Is the area a potential Problem Area? Yes No (If needed, explain on reverse.)	Community ID: ____ Transect ID: ____ Plot ID: B

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. ACER RUBRUM	T	FAC	9.		
2. Q. PALUSTRIS	T	FACW	10.		
3. FRAXINUS PENNSYLVANICA	T	FACW	11.		
4. "	H	FACW	12.		
5. GLYCERIA STRIATA	H	OBL	13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 100%

Remarks: ALSO PRESENT: POLYGONUM VIRGINIANA, CAREX SP.

HYDROLOGY

__ Recorded Data (Describe in Remarks): __ Stream, Lake, or Tide Gauge __ Aerial Photographs __ Other ✓ No Recorded Data Available Field Observations: Depth of Surface Water: NONE (in.) Depth to Free Water in Pit: NONE (in.) Depth to Saturated Soil: NONE TO 16" (in.)	Wetland Hydrology Indicators: Primary Indicators: __ Inundated __ Saturated in Upper 12 Inches __ Water Marks __ Drift Lines __ Sediment Deposits __ Drainage Patterns in Wetlands Secondary Indicators (2 or more required): __ Oxidized Root Channels in Upper 12 Inches __ Water-Stained Leaves ✓ Local Soil Survey Data ✓ FAC-Neutral Test __ Other (Explain in Remarks)

Remarks: MOSTLY BARE SURFACE; NO PRIMARY INDICATORS; FLARED TREE BASES. DRY SEASON SITE VISIT.

SOILS

PLOT B

Map Unit Name (Series and Phase): CANANDAGUA

Drainage Class: PD

Taxonomy (Subgroup): MOLLIC ENDOAQUEPTS

Field Observations Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-5		10YR 2/1	—		SiL
5-15		2.5Y 5/2	2.5Y 5/1	5%	SiL
			~~10YR 4/4~~	~~10%~~	
			10YR 6/4	5%	
15+		2.5Y 5/2	10YR 6/4	20%	SL

SAND + MOTTLING INCREASE WITH DEPTH

Hydric Soil Indicators:

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ✓ Reducing Conditions
- ✓ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ✓ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks: MEETS NTCHS INDICATOR F3.

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	Yes No (Circle)	Is this Sampling Point Within a Wetland? (Circle) Yes No
Wetland Hydrology Present?	Yes No (LIKELY)	
Hydric Soils Present?	Yes No	

Remarks: BROAD FLAT AREA, MOSTLY BARE SURFACE. PERIMETER DITCH ONLY ~2FT DEEP WITH HIGH BERMS. NOT LIKELY TO AFFECT WATER TABLE BEYOND IMMEDIATE VICINITY. RELATIVELY UNDISTURBED HYDROLOGY.

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: KLYDELL WETLANDS	Date: 10/27/00
Applicant/Owner: PROBST	County: NIAGARA
Investigator: WAKELEY, KLEISS, McDANNELL, KEMNER	State: NY
Do Normal Circumstances exist on the site? **Yes** No	Community ID:
Is the site significantly disturbed (Atypical Situation)? Yes **No**	Transect ID:
Is the area a potential Problem Area? Yes **No** (If needed, explain on reverse.)	Plot ID: C

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. POPULUS DELTOIDES	T	FAC	9.		
2. QUERCUS PALUSTRIS	T	FACW	10.		
3. "	S/S	FACW	11.		
4. ACER RUBRUM	T	FAC	12.		
5. "	S/S	FAC	13.		
6. CAREX SP.	H	—	14.		
7. (POSSIBLY C. INTUMESCENS)			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 100%

Remarks: ALSO: IRIS VERSICOLOR(?), CINNA ARUNDINACEAE, JUNCUS EFFUSUS, ASTER SP.

HYDROLOGY

___ Recorded Data (Describe in Remarks):
- ___ Stream, Lake, or Tide Gauge
- ___ Aerial Photographs
- ___ Other

X No Recorded Data Available

Field Observations:

Depth of Surface Water: NONE (in.)

Depth to Free Water in Pit: NONE (in.)

Depth to Saturated Soil: NONE TO 16" (in.)

Wetland Hydrology Indicators:

Primary Indicators:
- ___ Inundated
- ___ Saturated in Upper 12 Inches
- ___ Water Marks
- ___ Drift Lines
- ___ Sediment Deposits
- ___ Drainage Patterns in Wetlands

Secondary Indicators (2 or more required):
- ✓ Oxidized Root Channels in Upper 12 Inches
- ✓ Water-Stained Leaves IN DEPRESSIONS
- ✓ Local Soil Survey Data
- ✓ FAC-Neutral Test
- ___ Other (Explain in Remarks)

Remarks: BUTTRESSED TREE BASES, MULTIPLE STEMS, HYPERTROPHIED LENTICELS ON DEAD SAPLINGS. DRY SEASON SITE VISIT.

SOILS

PLOT C

Map Unit Name (Series and Phase): CANANDAGUA

Drainage Class: PD

Taxonomy (Subgroup): MOLLIC ENDOAQUEPTS

Field Observations Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-7	A	10YR 3/1	MIXED w/ B MATERIAL TOWARD BOTTOM		SiL
7-16+	B	2.5Y 5/2	10YR 5/6 10YR 5/8	20%	SiL

Hydric Soil Indicators:

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ___ Reducing Conditions
- ✓ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ✓ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks:

MEETS NTCHS INDICATOR F3.

WETLAND DETERMINATION

Hydrophytic Vegetation Present? Yes No (Circle)
Wetland Hydrology Present? Yes No
Hydric Soils Present? Yes No

(Circle)
Is this Sampling Point Within a Wetland? Yes No

Remarks:

Approved by HQUSACE 3/92

DATA FORM
ROUTINE WETLAND DETERMINATION
(1987 COE Wetlands Delineation Manual)

Project/Site: KLYDELL WETLAND Applicant/Owner: PROBST Investigator: WAKELEY, KLEISS, MCDANNELL, KEPPNER	Date: 10/27/00 County: NIAGARA State: NY
Do Normal Circumstances exist on the site? **Yes** No Is the site significantly disturbed (Atypical Situation)? Yes **No** Is the area a potential Problem Area? Yes **No** (If needed, explain on reverse.)	Community ID: ___ Transect ID: ___ Plot ID: A

VEGETATION

Dominant Plant Species	Stratum	Indicator	Dominant Plant Species	Stratum	Indicator
1. ACER RUBRUM	T	FAC	9.		
2. QUERCUS PALUSTRIS	T	FACW	10.		
3. ACER RUBRUM	S/S	FAC	11.		
4.			12.		
5.			13.		
6.			14.		
7.			15.		
8.			16.		

Percent of Dominant Species that are OBL, FACW or FAC (excluding FAC-). 100 %

Remarks: ALSO PRESENT: Q. BICOLOR

HYDROLOGY

__ Recorded Data (Describe in Remarks): __ Stream, Lake, or Tide Gauge __ Aerial Photographs __ Other ✓ No Recorded Data Available Field Observations: Depth of Surface Water: NONE (in.) Depth to Free Water in Pit: NONE (in.) Depth to Saturated Soil: NONE TO 16" (in.)	Wetland Hydrology Indicators: Primary Indicators: __ Inundated __ Saturated in Upper 12 Inches __ Water Marks __ Drift Lines __ Sediment Deposits __ Drainage Patterns in Wetlands Secondary Indicators (2 or more required): __ Oxidized Root Channels in Upper 12 Inches ✓ Water-Stained Leaves ✓ Local Soil Survey Data ✓ FAC-Neutral Test __ Other (Explain in Remarks)

Remarks: BARE SOIL, PROBABLY FROM INUNDATION. NO HERB LAYER. FLUTED TREE BASES. SOIL CRACKS UPON DRYING.

SOILS

PLOT A

Map Unit Name (Series and Phase): CANANDAGUA

Drainage Class: PD

Taxonomy (Subgroup): MOLLIC ENDOAQUEPTS

Field Observations Confirm Mapped Type? Yes No

Profile Description:

Depth (inches)	Horizon	Matrix Color (Munsell Moist)	Mottle Colors (Munsell Moist)	Mottle Abundance/Contrast	Texture, Concretions, Structure, etc.
0-8		10YR 2/1	—		SiL
8-12		2.5Y 6/1	10YR 3/2 10YR 5/6	20% 10%	SiL
12-16+		2.5Y 6/2	10YR 5/6	40%	SiL

Hydric Soil Indicators:

- ___ Histosol
- ___ Histic Epipedon
- ___ Sulfidic Odor
- ___ Aquic Moisture Regime
- ✓ Reducing Conditions
- ✓ Gleyed or Low-Chroma Colors
- ___ Concretions
- ___ High Organic Content in Surface Layer in Sandy Soils
- ___ Organic Streaking in Sandy Soils
- ✓ Listed on Local Hydric Soils List
- ___ Listed on National Hydric Soils List
- ___ Other (Explain in Remarks)

Remarks:

MEETS NTCHS INDICATOR F3.

WETLAND DETERMINATION

Hydrophytic Vegetation Present?	Yes (circled)	No	(Circle)
Wetland Hydrology Present?	Yes (circled)	No	
Hydric Soils Present?	Yes (circled)	No	

(Circle)

Is this Sampling Point Within a Wetland? Yes (circled) No

Remarks:

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

308 South Airport Road
Pearl, Mississippi 29208

November 2, 2000

MEMORANDUM

TO: James S. Wakeley, Wetlands Branch, ERDC
FROM: Barbara A. Kleiss, Supervisory Hydrologist, USGS bak
RE: Wetland hydrology observations at the Klydell Wetlands, at Meadow and Kinkead Streets, in North Tonawanda, Niagara County, New York

Background

The project area involves about 17.95 acres of land adjacent to the Klydell Wetlands, at the intersection of Meadow and Kinkead Streets, in North Tonawanda, Niagara County, New York. Two independent wetland delineations have been performed on this property; one by a consulting firm, the other by the New York Department of Environmental Conservation (NYDEC). The consulting firm asserts that the property has 3.24 acres of wetlands, while the NYDEC claims a larger amount. One of the points of contention between these two wetland determinations deals with the extent of the property that possesses wetland hydrology. During a field investigation on October 27, 2000, this issue was examined and the following memorandum reviews issues associated with the wetland hydrology on this property.

Seasonal Timing of Wetland Hydrology Assessment

In order to be defined as a wetland, an area must exhibit wetland hydrology, along with wetland vegetation and hydric soils. According to the 1987 U.S. Army Corps of Engineers Wetland Delineation Manual, wetland hydrology is defined as inundation or saturation to the surface continuously for at least 5 percent of the growing season in most years. The growing season in northwestern New York is defined by the Natural Resources Conservation Service in the Niagara County soil survey as the period between April 15 and October 31. Therefore, for wetland hydrology to exist on this site, an area must be saturated or inundated for 10 consecutive days during the growing season.

Rainfall is fairly evenly distributed throughout the year (fig. 1). However, average daily maximum temperatures are not evenly distributed (fig. 2).

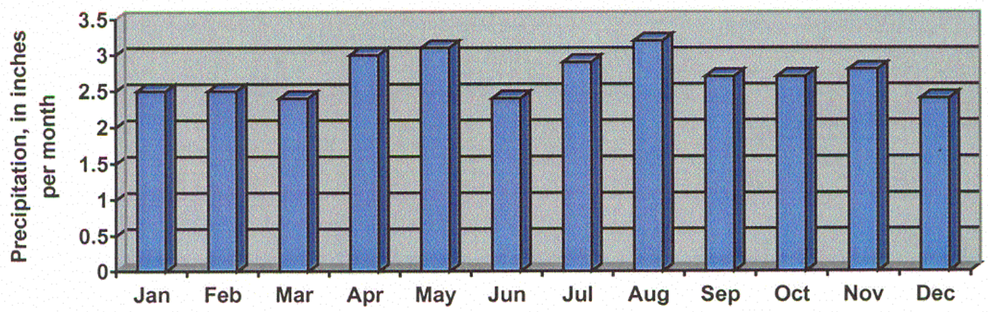

Figure 1. Monthly precipitation at Lockport, New York, based on a 30-year period of record. (Soil Survey of Niagara County, New York, 1972.)

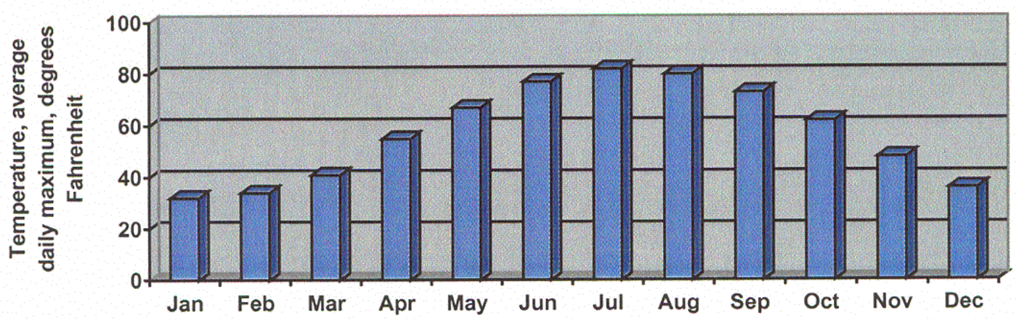

Figure 2. Average daily maximum temperature at Lockport, New York, based on a 30-year period of record. (Soil Survey of Niagara County, New York, 1972.)

The average temperature can be used as a surrogate for the periods during the year when biological activity and evaporation are at their highest. Thus, the periods of highest temperature are often periods of high evapotranspiration (that is, the combination of evaporation and the transpiration of the vegetation). When determining whether an area possesses wetland hydrology, it is necessary to evaluate the area during the growing season, but before evapotranspiration rates exceed soil moisture excesses, creating a moisture deficit in the soils. In northwestern New York, the optimum time for this evalution is likely to be from April 15 to around the end of May.

Unfortunately, all of the investigations to date on the Klydell Wetlands near the intersection of Meadow and Kinkead Streets have been performed in the late summer and early fall when the site is likely to be at its driest. During this period of time, no direct measures of hydrology (such as standing water or saturated soils) have been noted. However, determinations made during this time frame cannot accurately be used to state that wetland hydrology is not present on the site. Because no observations for primary hydrologic indicators have been made during an appropriate time frame, wetland hydrology can only be estimated by using indirect indicators.

Indirect Indicators of Wetland Hydrology

Presence of Hydric Soils: The entire Meadow and Kinkead Street project area is mapped in the Soil Survey of Niagara County (NRCS, 1972) as having a Canandaigua soil. Steve Carlisle, a Soil Scientist for the Natural Resources Conservation Service in Seneca Falls, New York, confirmed this mapping designation on September 18, 2000. According to the soil description information provided in the soil survey, the Canandaigua soil series "consists of deep, poorly drained and very poorly drained, medium-textured to moderately fine textured soils." "Canandaigua soils, unless drained artificially, have water standing at the surface throughout spring and after each rainy period. The downward percolation of water is restricted by the high water table, as is the depth to rooting." Also, the soil survey states that for the Canandaigua soil, the depth to the seasonal high water table is from 0 to 0.5 foot below the surface, indicating that at least for some period of time the site is likely to be saturated due to a high water table. This soil description strongly suggests the presence of wetland hydrology across much of the site. Additionally, hydric soil indicators, particulary gleying and iron concentrations, whose formation is dependent upon reduced conditions due to high water and fluctuating water tables, were found in shallow pits at sampling sites at several places on the property, again suggesting the presence of wetland hydrology.

Presence of Hydrophytic Vegetation: Hydrophytic vegetation is that which occurs in areas where the frequency and duration of inundation or soil saturation is sufficient to exert a controlling influence in the plant species present. Field observations of the vegetation showed the site to be dominated be red maple, pin oak, cottonwood and green ash, all of which are considered facultative or facultative wetland species. Semi-quantitiative measurements taken by both the Corps of Engineers and the consultant indicated that more that 50 percent of the dominant plant species forming all strata were rated as being faculatative or wetter plant species, showing that hydrophytic vegetation is present across much of the site. It follows, therefore, that for this wetland vegetation to be present, the site is also likely to have wetland hydrology present.

Other Wetland Indicators: Other indications that an area may have standing water for a fairly long period of time found on the Klydell Wetlands site include bare ground (or lack of herbaceous understory) consistent with standing water and publicly available photographs which show water standing on the forest floor (figs. 3 and 4). However, the dates and the locations of these photographs have not been determined, nor does the presence of water in a single photo firmly establish that the area remains flooded for a sufficient period of time to be delineated as a wetland.

Figure 3. Standing water in the wetlands in the vicinity of the project area. *(Picture from the Citizens for a Green North Tonawanda web site. Retrieved from* ***http://www.geocities.com/rainforest/vines/3317*** *on October 31, 2000. The location and dates of photos have not been verified.)*

Figure 4. Klydell Wetlands in the summer showing standing water. *(Picture from the Citizens for a Green North Tonawanda web site. Retrieved from* ***http://www.geocities.com/rainforest/vines/3317*** *on October 31, 2000. The location and dates of photos have not been verified.)*

Apparent Impacts of Hydrologic Alteration

A ditch that is approximately 3 meters wide and 0.5 meter deep traverses the eastern and northeastern perimeter of the property. While, in theory, this ditch could be draining water from the wetland site, in actuality it does not appear as though this ditch has a significant effect on the wetland hydrology of the site. There are two aspects which indicate this minimal influence. First, the ditch has a prominent berm on the west side where the spoil material from the ditch construction was placed that would retard the movement of water from the site into the ditch. Secondly, the growth of mature trees on the berm of the ditch indicates that the ditch has been in place for an extended period of time. Many of the saplings and understory vegetation in the project area are younger than the ditch, and the vegetation is still dominantly hydrophytic, showing that the area is still wet enough after ditch construction to support wetland vegetation. Thus, the ditch appears to be having a minimal effect on the wetland hydrology of the site.

Summary

Hydrologic measurements and observations on the Kinkead Avenue and Meadow Drive site have not been made in the mid-April to late May time frame, which is necessary to firmly establish whether wetland hydrology is present on the site. However, a variety of indirect indicators, including the presence of hydric soils, the presence of hydrophytic vegetation, the lack of understory vegetation in low areas, and undated photographs taken in the vicinity showing standing water suggest that wetland hydrology is likely to be present in an area larger than that defined by the consulting firm who submitted a wetland delineation for the site.

If more definitive information regarding the wetland hydrology of this site is needed, more site-specific investigations are required. This could be done in a couple of ways. Frequent observations of the extent and duration of floodwater and/or saturation due to a high water table could be made by field personnel. Secondarily, water-level recorders and shallow wells could be installed. In either case, it would be critical to determine the best time of the year for observations to be made, and to determine whether or not the year in which the observations took place is a normal or average rainfall year.

Swimming Performance of the Topeka Shiner (*Notropis topeka*), an Imperiled Midwestern Minnow

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ABSTRACT.--- The Topeka shiner (*Notropis topeka*) is imperiled by extensive changes in stream hydrology. Responses of shiners to changes or variation in stream hydraulics, however, have not been quantified, hampering conservation efforts. We quantified swimming endurance and behavior for Topeka shiners in a laboratory swim tunnel. Sustained swimming (> 200 minutes) was observed at water velocities of 25-40 cm/s. Prolonged and burst swimming (approximately 10 minutes to less than 0.1 minute) was observed at water velocities of 40-75 cm/s and endurance was negatively correlated with water velocity. Endurance was not significantly correlated with fish size, but larger individuals (4.4-5.5 cm standard length) exhibited greater sustained and burst swimming speed than smaller individuals (3.0-4.2 cm standard length). Oral grasping of submersed structure, a previously undescribed behavior in stream fishes, was frequently employed at moderate water velocities (40-50 cm/s) and may limit downstream displacement of shiners during freshets. Topeka shiners are capable of inhabiting and traversing water velocities greater than those which they typically inhabit. Fishways and culverts, therefore, may be employed to facilitate dispersal and recolonization. Swimming endurance data are used to determine optimal size and water velocities for such structures.

INTRODUCTION

The Topeka shiner (*Notropis topeka*) is experiencing "precipitous declines" in abundance and range and could become extirpated from some state ichthyofaunas (Morris et al., 1974; Pflieger, 1997). Historically, this species was broadly distributed in streams of the Mississippi, Missouri, Kansas, and Arkansas River drainages (Bailey and Allum, 1962). Apparent reductions in abundance and range were noted as early as 1959 (Minckley and Cross, 1959), but its status as an imperiled species is not unanimously recognized. Three states list the species: Missouri as "endangered," Kansas as "in need of conservation," and Minnesota as "special concern" (Cross and Collins, 1995; Schmidt, 1996; Pflieger, 1997). The Topeka shiner is not listed by South Dakota, Nebraska, or Iowa, but the United States Fish and Wildlife Service recently proposed that the Topeka shiner be recognized federally as an endangered species (Federal Register Vol. 62, No. 206).

Various causes have been suggested for the decline of the Topeka shiner, principally agricultural and flood control practices that alter stream hydrology (Pflieger, 1997). The Topeka shiner characteristically inhabits large pools with coarse substrates in small, clear, cool prairie and upland streams (Cross and Collins, 1995; Pflieger, 1997). Stream flow is required to maintain water clarity, reduce temperatures, clean preferred substrates, and facilitate movements within and among streams. High water velocities, however, are avoided by the fish and can have deleterious effects on population size; reproductive failure occurs when flows are elevated and sustained (Minckley and Cross, 1959). Fishways and culverts could provide Topeka shiners with access to suitable habitats, but to ensure realistic assessments of habitat suitability and likelihood of fish movements, a descriptive, quantitative model of swimming ability is required.

Swimming performance of fish (reviewed in Beamish, 1978; Videler and Wardle, 1991) is readily studied in laboratory swim tunnels, or flow tanks (Vogel and LaBarbera, 1978). Swim tunnels are especially useful for studies of individual small fish because they allow precise replication of water velocities in a uniform environment, and because they permit observations of concurrent biological responses, such as swimming, associated behaviors, and displacement. Depending on duration and energy source, swimming speeds can be classified as sustained, prolonged, and burst (Webb, 1975). Sustained swimming speeds can be maintained for long periods (> 200 minutes) without resulting in muscular fatigue. Prolonged speeds are of intermediate duration (< 200 minutes, > 30 seconds) and eventually result in fatigue. Burst swimming results in the highest speeds attained by fish, but is only maintained for short periods (< 30 seconds) due to the accumulation of anaerobic metabolites. Our objectives were to: i) quantify sustained, prolonged, and burst swimming speeds of Topeka shiners by measuring endurance (time-to-fatigue) over a range of water velocities in a laboratory swim tunnel; ii) describe behaviors associated with swimming that might influence fish movements; iii) estimate maximum water velocities in fishways of varying dimensions that are traversable by Topeka shiners.

MATERIALS AND METHODS

Fifty Topeka shiners were seined 9 June 1998 from Clear Fork Creek (Pottawatomie County, Kansas) and a tributary to Deep Creek (Riley County, Kansas) in the Kansas River drainage and shipped to Waterways Experiment Station (Vicksburg, Mississippi) in insulated boxes. Upon arrival, fish were transferred to two, 300 liter Living Streams Model 510 (Frigid Units, Toledo, Ohio) and held at 20 °C. Fish were kept on a 12:12 h day:night cycle, and lighting during the day was provided by overhead florescent fixtures 90 cm above water surface. No mortality occurred prior to or at any time during the study. Fish were fed TetraMin Staple Flake Food three times daily.

Swimming tests were performed in a 100 liter Blazka-type swim tunnel (Beamish, 1978). It was constructed of Plexiglas, with a cylindrical working section 39 cm long and 15 cm wide. Water velocity was produced with a 3-blade propeller powered by a Dayton Model 2Z846C electric motor (Dayton Electric Manufacturing Co., Chicago, Illinois). Two circular "honeycombs" constructed of 12-20 mm diameter PVC functioned as collimators that straightened flow and reduced turbulence within the swimming chamber of the tunnel. Water velocities ranged from 5 - 75 cm/s and were calibrated with a Marsh-McBirney Flo-Mate 2000 water velocity meter. Temperature in the swim tunnel was maintained at 20 °C with a Remcor Liquid Circulator (Glendale Heights, Illinois).

Fish acclimated for 14 days. Prior to testing, 8-10 fish were isolated together within the holding tank and were fasted 24 h to achieve a postabsorptive state. Individual fish were carried to the swim tunnel in a water-filled plastic container that minimized movements. After placement in the working section, an individual fish was allowed a 1.5 h habituation period, during which water velocity ranged from 0 to 25 cm/s; after 40 min of zero velocity, speed was increased 5 cm/s every 10 min. The stepwise increase in speed during the habituation period helped fish orient and habituate to sudden increases in water velocity. Following the habituation period, water velocity was rapidly increased (over 2 - 4 s) to a designated test velocity and time-to-fatigue (endurance) measured with a stopwatch. Tests (except sustained speeds) terminated in fatigue, when a fish could no longer maintain position against water current without bracing or impinging against the downstream retaining screen and would not respond to mechanical stimulation (tapping of retaining screen). Swimming behavior during trials was noted and duration of anomalous behavior recorded. All fish were tested once, and 21 fish were re-tested following 10 days rest. After each trial, standard length (SL) was measured to the nearest 0.1 cm. Additional trials were conducted with groups of four fish swimming simultaneously at speeds 40- 65 cm/s to ascertain effects of schooling on swimming performance. Group trials were stopped after two of the four fish fatigued.

Speeds that fish maintained for at least 200 min were considered sustained swimming speeds and excluded from analyses designed to generate predictive models. Fish that would not swim in the tunnel, even after extending the habituation period, were considered non-performers and removed from the tunnel (n = 7). Non-performers (n = 7) and fish exhibiting excessive anomalous behavior (n = 7) were not included in models. Variation in endurance due to swimming speed and standard length was first examined with least squares stepwise multiple regression. Endurance was the dependent variable and standard length and water velocity (i.e., swimming speed) were independent variables. If standard length was not significantly correlated with endurance, a univariate regression model was constructed relating endurance as the dependent variable to water velocity as the independent variable. Due to low numbers of individuals greater than 4.4 cm SL (n = 7), desired level of replication at each speed increment of fish this size was unattainable.

Peake et al. (1997) developed an equation to predict passable water velocities as a function of swimming speed, distance, and endurance:

$$V_f = V_s - (D/ E_{vs})$$

in which V_f is ambient water velocity (cm/s) within the obstacle (weir, fishway, etc.), V_s is swimming speed (cm/s), D is distance of the obstacle (cm), and E_{vs} is endurance (seconds) at V_s. Equation can be used to predict maximum water velocity capable of being traversed by fish moving through channels, fishways, culverts, or other high velocity obstacles. We used this relationship to predict maximum water velocities traversable by Topeka shiners over a range of distances from 1-15 m. A range of swim speeds, 40-70 cm/s, and corresponding endurance for small fish (predicted by the empirically-based linear regression model described above), was substituted iteratively into this equation to determine the maximum velocity traversable for each distance. A curvilinear regression model was subsequently developed for the relationship between distance (independent variable) and maximum water velocity (dependent variable). All regression analyses were performed using Statistica software for personal computers (StatSoft Inc, Tulsa, OK).

RESULTS

Swimming endurance of individual fish was effectively measured in 57 trials with shiners ranging 3.0 - 5.5 cm SL at time of measurement (Fig. 1). Frequency distribution of fish size indicated three size categories: 3.0-4.2 cm, mean = 3.7 cm; 4.4-4.7 cm, mean = 4.5 cm; 5.1-5.5 cm, mean = 5.3 cm. To address size-related differences in swimming endurance, the latter two size classes were pooled into a single size class representing larger fish.

Endurance was negatively correlated with water velocity, and differed between size classes, but was not affected by fish swimming in groups (Fig. 2). Sustained swimming was observed at 30-40 cm/s. One fish, 3.6 cm SL, was allowed to swim indefinitely at 30 cm/s and swam 20 hours. At higher speeds, fatigue was usually observed within 10 min. Including both size classes of fish, but only those data in which fatigue was observed (prolonged and burst speeds), the overall model for predicting endurance was:

$$\underline{y} = -0.042\underline{x}_1 + 0.179\underline{x}_2 + 1.579 \quad (\underline{F}_{2,43} = 38.4;\ \underline{P} < 0.001;\ \underline{R}^2 = 0.64)$$

in which $\underline{y}$ is $\log_{10}$ endurance (min), $\underline{x}_1$ is water velocity (cm/s), and $\underline{x}_2$ is standard length (cm). Although the model is significant ($\underline{P}<0.05$), variation in endurance attributable to standard length was not ($\underline{P} = 0.071$).

Small (3.0 - 4.2 cm SL) and large (4.4 - 5.5 cm SL) shiners could maintain speeds ≤ 35 cm/s and ≤ 40 cm/s for a minimum of 200 min, respectively, and these were considered sustained swimming speeds (Fig. 2). For small fish, endurance decreased linearly from 40 to 75 cm/s and maximum prolonged speeds occurred between 50 - 60 cm/s. Swim speeds from 60 - 75 cm/s were generally maintained for less than 30 s and represent burst swimming speeds. For large fish, endurance at 45 - 60 cm/s was typically within the range of values for smaller fish. At 70-75 cm/s, however, larger fish had greater endurance than smaller individuals. For prolonged and burst speeds, there was a significant linear relationship between swimming endurance and speed in the small and large size group, respectively:

$$\underline{y} = -0.045\underline{x} + 2.36 \quad (\underline{F}_{1,32} = 68.0;\ \underline{P} < 0.001;\ \underline{R}^2 = 0.68)$$

$$\underline{y} = -0.024\underline{x} + 1.497 \quad (\underline{F}_{1,10} = 6.34;\ \underline{P} = 0.03;\ \underline{R}^2 = 0.39)$$

in which $\underline{y}$ is $\log_{10}$ endurance (min) and $\underline{x}$ is water velocity (cm/s). Within each category (small fish and large fish), individual fish size was not significantly correlated with swimming endurance ($P > 0.500$) and percent variance accounted for by models based on both independent variables (water velocity and fish size) was no higher (< 1%) than models using water velocity as the sole independent variable. No increase in group endurance relative to individual endurance was observed at speeds 40 - 65 cm/s (Fig. 2).

In 36 of 64 trials, Topeka shiners grasped the upstream retaining screen with their mouth and held position without swimming (Fig. 3). During oral grasping, fish held onto the screen while their body swayed in the current like a "flag in the wind." Precise biomechanics of oral grasping were not discernible, except that the entire mouth sometimes engulfed the wire mesh, and occasionally the lower jaw and operculum moved. Typically, fish held onto the screen for 3 - 4 s at a time, but some individuals held for periods up to one minute. Although grasping time was negligible for most individuals, 7 fish grasped for greater than 15% of the total bout at speeds ranging from 40 to 75 cm/s, and their swimming endurance was substantially higher than all other individuals at the same speeds and most fish at any speed. These 7 fish were interrupted before fatigue occurred but swim time ranged from 5.0 min (at 75 cm/s) to 102.0 min (at 40 cm/s). Grasping in other individuals occurred most frequently at 35-50 cm/s but decreased substantially at higher water velocities.

Predicted maximum water velocity traversable by small Topeka shiners in fishways decreased logarithmically with fishway length (Fig. 4). Traversable water velocities were comparatively high, 51-61 cm/s, only for distances less than 3 m. Substantially lower velocities, < 40 cm/s, were traversable for distances > 8 m. Curve was constructed for small Topeka shiners but would be applicable to larger individuals as conservatively low estimates for traversable maximum water velocities.

DISCUSSION

Topeka shiners typically occupy pool and slackwater habitats (Minckley and Cross, 1959) and avoid water velocities > 10 cm/s (J. Hatch, pers.comm.), but field and laboratory observations indicate substantial physical tolerance for stronger flows. Topeka shiners are observed in riffles when population densities are high (Minckley and Cross, 1959) and current is required to breed Topeka shiners in captivity (R. Katula personal communication). Sustained swimming speeds of Topeka shiners measured in this study are comparable to those of two minnows inhabiting large rivers, the emerald shiner, *Notropis atherinoides*, and the Mississippi silvery minnow, *Hybognathus nuchalis* (S.R. Adams et al., unpublished data). Sustained swimming at moderate water velocities, although not representative of typical preferred habitat, suggests potential for remnant or isolated populations to rapidly invade uninhabited waters (e.g., Starrett, 1950).

Sizes of Topeka shiners tested are representative of natural populations in Kansas. Our three size categories correspond closely to measured sizes of fish Ages I, II, and III: 3.5 cm, 4.3 cm, and 5.3 cm respectively (H. Kerns, unpublished data). The two size classes used in our analyses here represent Age I subadults and small adults (3.0-4.2 cm SL), and Age II and III larger adults (4.3-5.5 cm SL). Although size was not significantly correlated with endurance in any of the linear regression models, larger fish were better swimmers than small fish (Fig. 2). Sustained and burst swimming speeds were higher for larger fish than for smaller fish. This suggests size thresholds may exist, attainment of which substantially increases swimming endurance at individual water velocities. For example, at 40 cm/s, a shiner 4.0 cm SL swam only 3.5 min; an individual 4.1 cm SL swam 14.2 min, and shiners 4.4-5.5 cm SL all swam for 200 min or more. Fish > 4.3 cm SL comprise a relatively small percentage of natural populations, but are overwhelmingly dominated by sexually mature adults (H. Kerns, unpublished data). Such fish may need greater swimming capabilities than smaller fish to migrate between pools to suitable spawning habitat.

In addition to swimming, some benthic fishes living in high velocity environments, such as sturgeon and darters, can maintain position by appressing themselves to the substrate using fins and body shape to minimize lift and maximize drag (Matthews 1985; Adams et al. 1997). To our knowledge, a non-swimming form of station-holding behavior has never been documented in an open water fish. Oral grasping is a complex behavior that likely has energetic benefits in strong currents, but to what extent grasping may influence longitudinal movements of Topeka shiners is unknown. Swimming was forced, not voluntary, in our experiments and represent swimming capabilities rather than swimming preferences. Grasping behavior was initiated at water velocities > 30 cm/s and increased in frequency with increasing velocity, suggesting that Topeka shiners prefer not to swim at water velocities > 30 cm/s; low frequencies of oral grasping at 55-70 cm/s indicate that hydraulic forces exceed the grasping abilities of fish.

The small streams inhabited by Topeka shiners are subject to periodic droughts and freshets during which oral grasping might retard downstream displacement and enhance persistence within a stream reach. Long-term location fidelity could enhance geographic isolation of individual populations. This is supported by recent genetic studies indicating that the Topeka shiner is a "regional derivative" of the more broadly distributed sand shiner, *Notropis stramineus* (Schmidt and Gold, 1995) and that differentiation among populations of Topeka shiners within a single state and within a single stream is significant (D. Bergstrom, T. Holtsford, and J. Koppelman, unpublished data).

Swimming performance data can be applied to fish passage through fishways and culverts (Wales, 1950; Jones et al., 1974; Belford and Gould, 1989; Peake et al., 1997). For Topeka shiners, effective fishways with water velocities less 35 cm/s could be of indefinite length since fish could easily pass through them without experiencing fatigue. Such low velocities may be hydraulically unrealistic options for fishway engineers. Fishways with water velocities > 60 cm/s, however, necessitate burst swimming from Topeka shiners, which in turn requires rest periods for fish to repay oxygen debts (Nelson, 1994). Such high velocity fishways would necessitate very short lengths or structurally induced slack water areas, such as pools or baffles, in or behind which fish could rest. Fishways designed to accommodate prolonged swimming speeds of Topeka shiners, though, could provide hydraulic characteristics that enhanced ability of shiners to negotiate the fishway while preserving the ability of the fishway to discharge water. The lowest effective water velocity through such a passageway would optimize fish passage since it would minimize energetic stress to fish. Though fish possess the swimming ability to pass a barrier, factors other than water velocity (light regime, depth, turbulence, sound, rate of velocity increase, etc.) may influence fish passage (Hocutt, 1980; Kynard, 1993). It should be noted that many factors effect the swimming performance of fish (i.e. temperature, oxygen, photoperiod, season, sex, etc.) which were beyond the scope of this study. Ultimately, a passage design to restore Topeka shiners to former habitats will require field-tests to determine passage efficiency.

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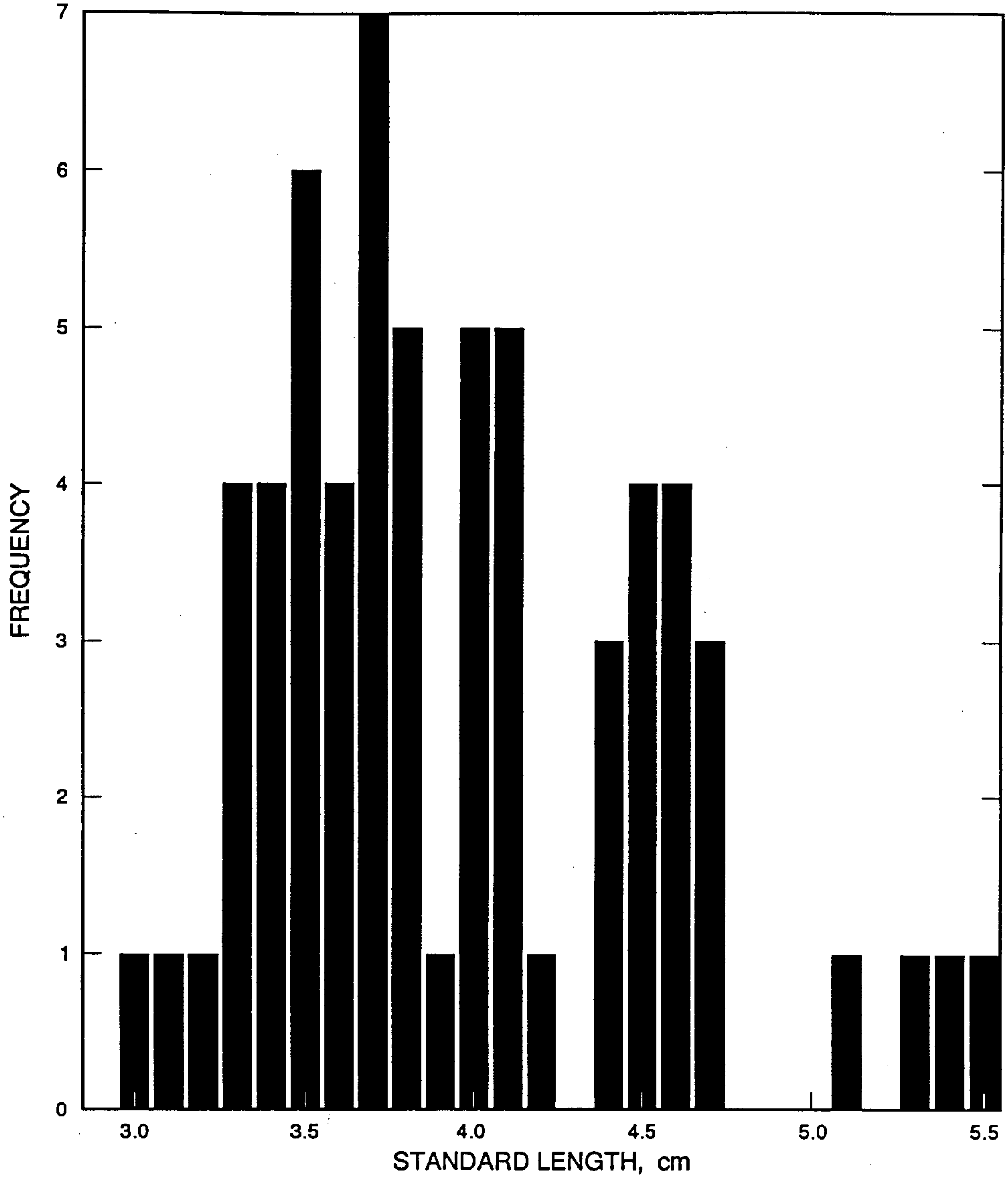

Figure 1. Size range and frequency of Topeka shiners tested for swimming endurance (n=63).

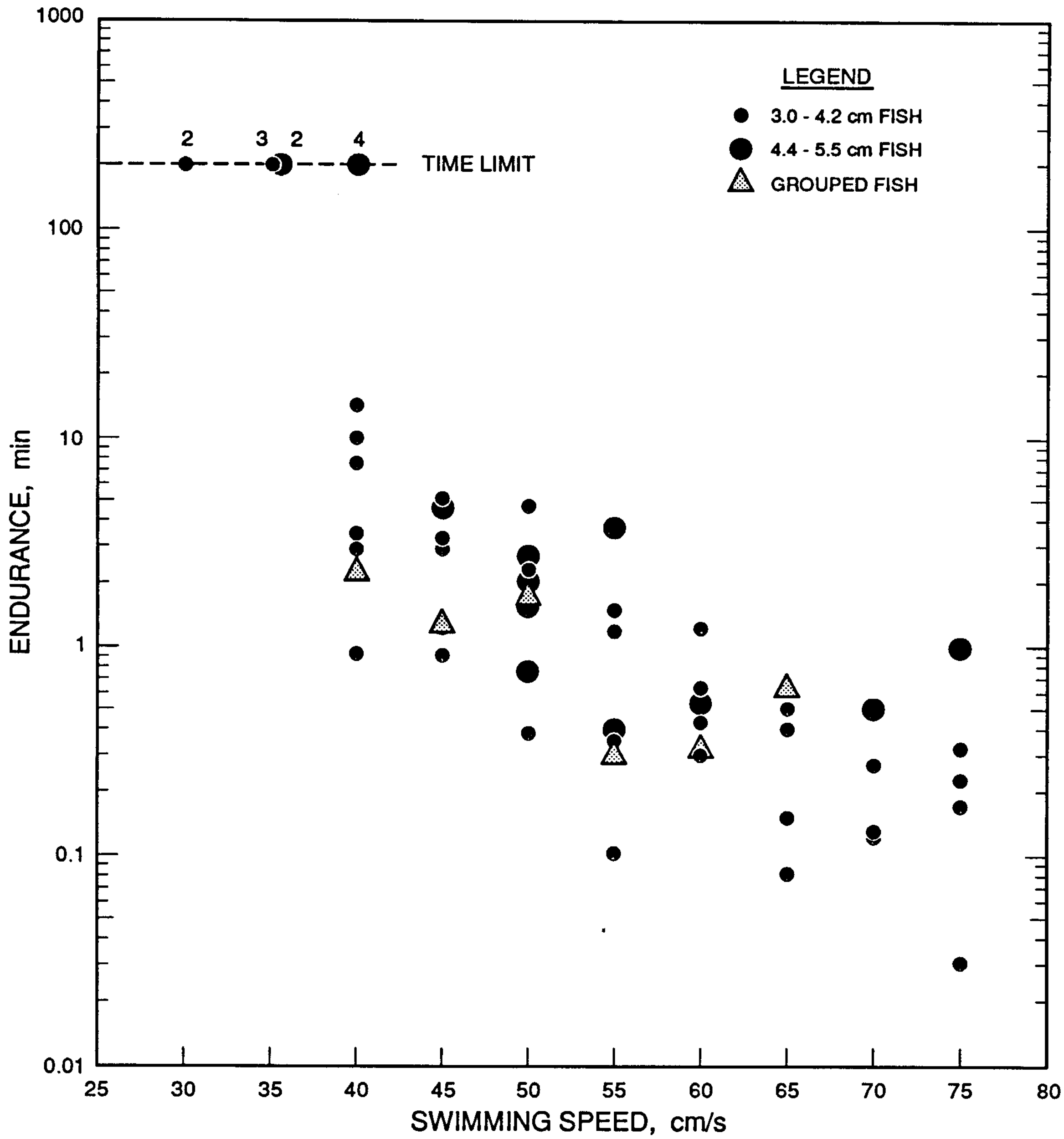

Figure 2. Semilog plot of swimming endurance (min) of Topeka shiners and swimming speed (i.e., water velocity, cm/s) in a Blazka swim tunnel. Circles represent data for individual fish (n=57), triangles for individual groups of four fish run simultaneously (n= 6). Horizontal dotted line at 200 minutes represents sustained swimming speed with the number of observations stated.

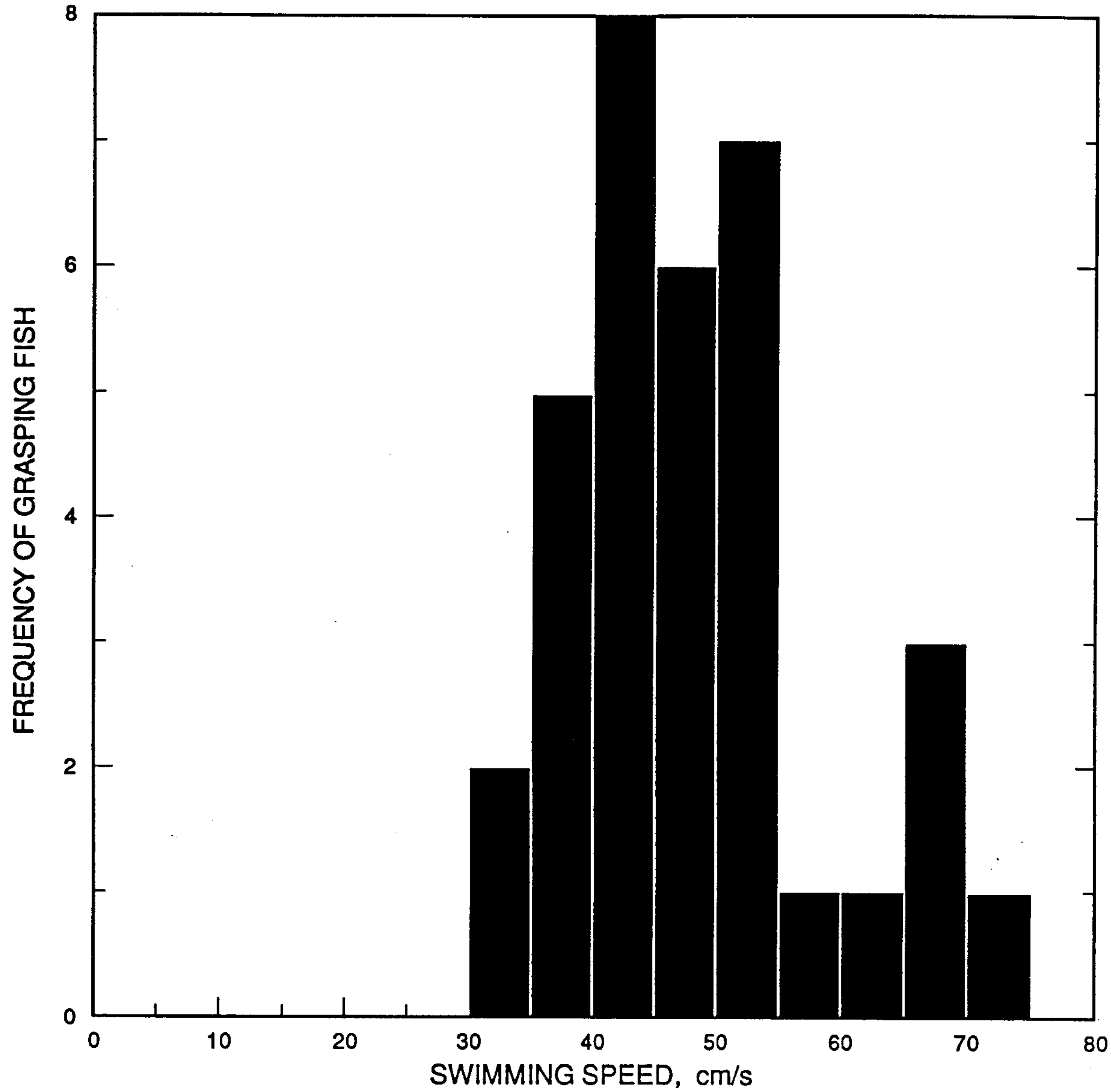

Figure 3. Occurrence of oral grasping by Topeka shiners in relation to water velocity (n=36). Oral grasping was not observed at water velocities < 30 cm/s.

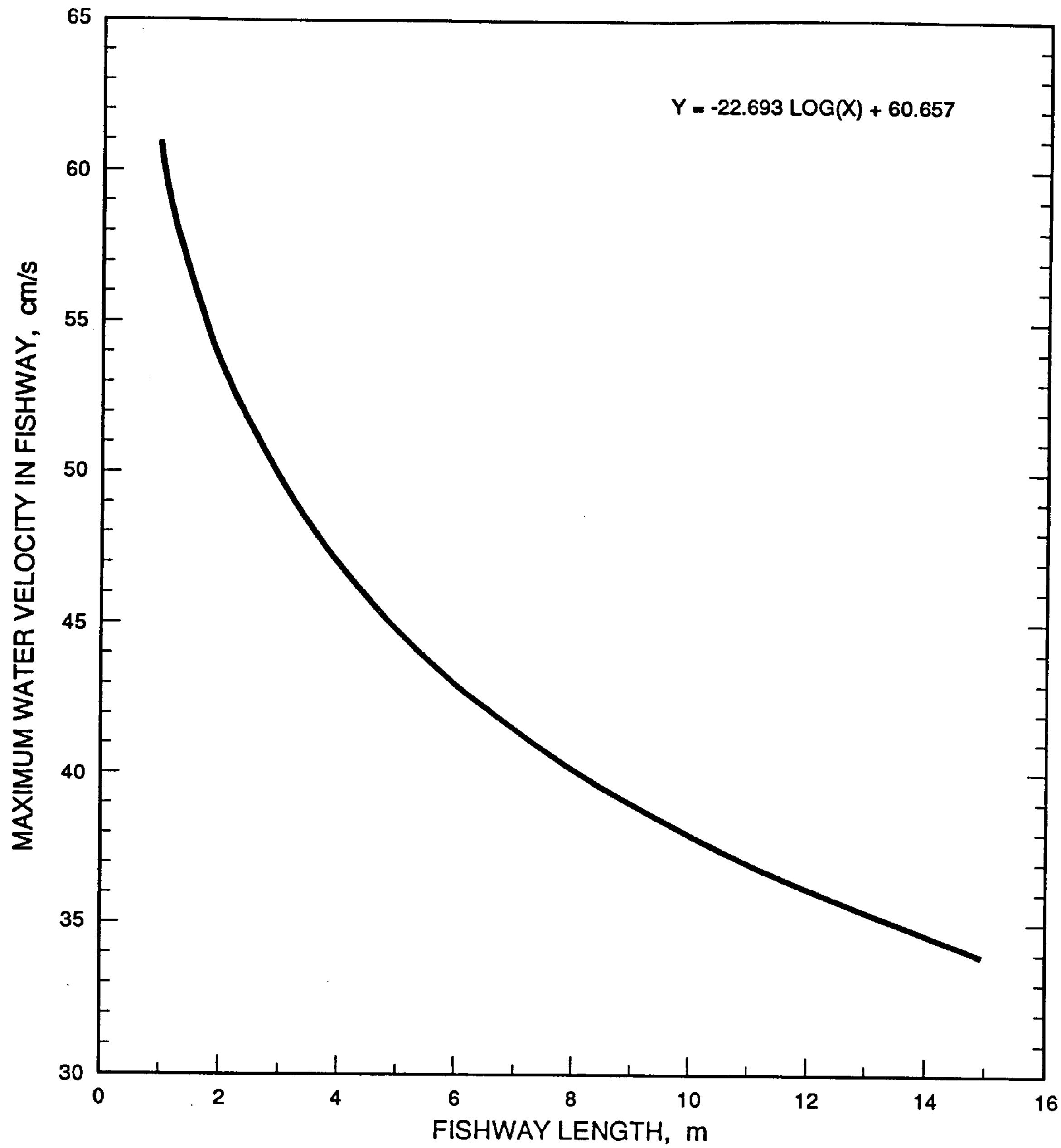

Figure 4. Logarithmic regression curve and model for the relationship between maximum traversable water velocity (cm/s) and length of fishway (m) for Topeka shiners.

WRAP RESPONSE # 01-02: Dredging Permit for Mobley Construction Company In the White River, Arkansas: Paddlefish Spawning Habitat in the Exclusion Zone

Background

Mobley Construction Company has requested a dredging permit from the US Army Engineer Memphis District to mine sand from the White River channel above the mouth of the Black River. Memphis District, however, attached a special condition to the permit that prohibits dredging in a reach extending from Rivermile 259 (at the mouth of the Black River near Jacksonport, Arkansas) to Rivermile 274 (near Oil Trough, Arkansas) during the period March-May. This "exclusion zone" was established for this period to protect spawning and rearing grounds of fishes that reproduce in swift water habitats early in the fish reproductive season. Conspicuous among these fishes is the paddlefish (*Polyodon spathula*). The paddlefish is listed as an inventory element (= special concern) by the Arkansas Natural Heritage Commission (Cindy Osborne, pers.comm.), as imperiled (endangered, threatened or special concern) by resource agencies in multiple states (Schmidt, 1996), and as "vulnerable" by the American Fisheries Society (Warren et al., 2000).

Large specimens of paddlefish were first reported in the White River over a century ago (Meek, 1894). Recently, there was a commercial fishery for roe (caviar) and currently White River paddlefish constitute one of only three large populations in the state of Arkansas (Robison and Buchanan, 1988). Paddlefish spawning areas are rarely delineated (Wallus, 1986), but environmental requirements for successful spawning are well-established (Crance, 1987). Requirements include: i) late winter or early spring rise in river stage coinciding with rising water temperatures $\geq 10\,^{\circ}C$; ii) coarse substrate; iii) moderate water depth. Mobley Construction Company and its consultant GBMc and Associates (GBMc) contend that these requirements are either not met in the exclusion zone, or, if met, are not distinctive to the exclusion zone. Mobley Construction Company requests "relief" from the special condition of the permit and maintains that by preventing it from dredging in the exclusion zone during the period Mar-May, the Memphis District is imposing economic hardship to the company.

On 19 Sep 00, a meeting was held among representatives from Mobley Construction Company, GBMc, Memphis District (CEMVM), and the US Army Engineer Research and Development Center at Waterways Experiment Station (CEWES). Attendees were Bryce Mobley and Phyllis Hardin (Mobley Construction Company), Roland McDaniel (GBMc), Judy O. DeLoach, Patricia Jones, Linda Boyd, Larry Watson, and Colonel Kreuger (CEMVM), and Jan Jeffrey Hoover (CEWES). Purpose of the meeting was to summarize and discuss findings of a report by GBMc on suitability of the exclusion zone as paddlefish spawning and rearing habitat.

GBMc concludes that "there is [sic] no data to support the presence of spawning activity upstream of the mouth of the Black River." Because paddlefish population data do not exist for this area, the general approach of the report is valid (i.e., review of data for specific physical factors known to influence paddlefish spawning), but the scope and methodology of "analysis" are flawed. subjective.

Habitat Assessment Criteria Addressed by the GBMc Report

The GBMc report considers several requirements associated with successful reproduction of paddlefish and then dismisses each. Each requirement is listed below along with contrasting opinions of GBMc and CEWES, and supporting rationale for the latter.

Water temperature – Report contends that appropriate water temperatures are not met in the White River. GBMc states that a minimal water temperature of 10 °C is required but that "actual spawning has been reported at 14 °C and most literature indicates the optimum temperature as 16-17 °C." GBMc presents water temperature data for 1997-2000 and concludes "optimum" water temperatures (14 – 17 °C) are not maintained until early to mid- April. Statement assumes that pre-spawning activities (i.e., staging) and spawning at cooler temperatures, which take place early in the season, are insignificant or non-existant, and that temperatures within this optimal range must be maintained for successful reproduction.

These assumptions conflict with field data and consensus of expert opinion. Pre-spawning, spawning, and successful incubation are documented for water temperatures < 13 °C, and/or prior to April, in Louisiana (Alexander, 1915), Tennessee (Pasch et al., 1980; Wallus, 1986), and Iowa (Southall and Hubert, 1984). Models derived from analyses of expert opinion indicate much broader ranges of optimal temperatures for spawning, incubation, and larval development, with lower values (<< 14 °C) providing functional or even optimal temperature for incubation and development (Crance, 1987). These models also indicate that "optimal" temperatures do not have to be continuously "maintained" to insure successful hatching and survival, only that a temperature range be maintained above some minimal value (e.g., 8 °C). Temperature data presented by GBMc indicate that "optimal" temperatures > 14 °C occurred sometime during the month of March or in late February in all four years, and that minimal functional temperatures for spawning ≥ 10 °C and for incubation > 8 °C occurred during most of March during each of the years. During one of the four years, "optimum" water temperatures were attained on 01 Mar, and near-optimum temperatures (12-17 °C) maintained during the entire month. Data indicate then that water temperature in the exclusion zone during March was suitable for reproduction during four out of four years, and "optimal" during one of those years.

Increased sustained flows - Report contends that because of flood control reservoirs upstream from the exclusion zone, spring flows are of insufficient magnitude and duration to support spawning. GBMc supports this contention with a 4 year-hydrograph for Batesville gage during the period 1991-1994. Assumption is that peak flows must be sustained for paddlefish to move into spawning grounds.

This assumption conflicts with established patterns of paddlefish movement and with hydrographic data for the White River. Paddlefish can move upstream incrementally, downstream into pools during falling water and then back upstream when water rises again (Russell, 1986). Paddlefish are capable of multiple spawns within a season and incubation is typically completed in less than 14 days (Purkett, 1961; Wallus, 1986; Yeager and Wallus, 1990). Almost two weeks are required at lower temperatures (10-14 °C) but less than 7 days are required at higher temperatures (15-21 °C). In the White River, individual paddlefish may occupy a short reach of river (e.g., < 5 river miles) for long periods of time before making substantial movements upstream and downstream (Filipek, 1990). Hence, a sufficient net increase in river stage (= discharge) during the spawning period will permit a net upstream movement of fish into favorable habitats if they are available, and if base discharge is maintained for a period of at least two weeks, then incubation will be completed. Paddlefish reproduction is documented for discharges of 10,000 - > 24,000 cfs (Russell, 1986) with greater reproduction occurring at higher discharges (Wallus, 1986).

Data for the Batesville gage during the 1987-1994 period of record indicate that conditions for successful reproduction occur during all but two years. Discharges were greater than 10,000 cfs. In 1991, however, the spring rise in water level was late (after 20 Mar); in 1992 elevated water levels were of very brief duration (10 days). During six of the eight years, however, base discharge (i.e., exclusive of peak flow) in late February and early March increased 1.6 – 2.5 times over that of winter lows and these discharges were maintained or exceeded for periods of 15-60 days. These data are available at: http://waterdata.usgs.gov/nwis.

Substrate – Report concedes (p. 4) that "substrate preferred for spawning activities probably occurs within the exclusion area." CEWES concurs. We know from direct observation that the coarse substrates preferred by spawning paddlefish are widespread in the exclusion zone (pers. obs.).

Water depth - Report indicates that optimal depth for spawning is 4 m (p. 1) and concedes (p. 4) that "there are sections with sufficient depth in the exclusion area." Consensus among paddlefish biologists is that there is a range of optimal depth for larval development of 2-5 m (Crance, 1987). We know from direct observations of channel morphology at low stages that preferred depths are available during higher stages in the exclusion zone.

Spawning data – GBMc reports that in 1989-1990 the Arkansas Game and Fish Commission (AGFC) tagged and released 360 fish, of which 29 were equipped with telemetry devices, and with the exception of a single fish recorded at RM 260, "there is no other definitive information to indicate Paddlefish [sic] use the area of the White River as a spawning area (p. 3)." Statement implies that a large number of fish were available to document spawning activity in the exclusion zone if it occurred there. The information on sampling effort is misleading, and in some cases incorrect.

According to the AGFC report, 360 fish were netted, but only 230 fish were equipped with external tags (Filipek, 1990). Of these, only about 10% were recovered (Steve Filipek, pers.comm.). Given the extent of the river involved (over 150 river miles), the likelihood that any of these individuals would occur in the exclusion zone during the spawning period and would then be recovered is low.

According to the AGFC report, 29 fish were equipped with telemetry devices, but 8 of these (captured in 1988) were difficult to track due to attenuation of signals (in fish with internal antennae) and data in the report were presented only for 20 fish captured in 1989-1990 (Filipek, 1990). Of these 20, only 8 were collected within 60 rivermiles of the exclusion zone. Three of these were collected near RM 200-201, but two of these were subsequently re-captured downstream shortly afterward and prior to being tracked. This left only six fish available for observation. Five of these were collected between RM 250-257: four were captured and tagged in late March 1989 after water levels had already risen, one was captured in mid-March 1990 nearly four weeks after river discharge doubled from 10,000 cfs to > 20,000 cfs. If these fish were going to migrate upstream in response to rising water, then they should have already done so.

In conclusion, only eight fish were tagged within 60 miles of the lower limit of the exclusion zone and all fish were tagged prior to the onset of spring rise in water levels. Only a subset of adult paddlefish spawn in any given year and these make spawning migrations with the onset of rising water levels. The likelihood of tracking one of these fish into the exclusion zone was low because few, if any fish, were available to migrate there.

Stocking program – GBMc states that the fact that AGFC does not stock paddlefish in the White River "indicates that a healthy reproducing population is present (p. 5)." This is incorrect. Lack of stocking does not indicate that a population needs no protection. AGFC reports that fish are not stocked in the White River because the agency does not want to stock less hardy (i.e., hatchery-reared) fish into an existing population of paddlefish (S. Filipek, pers.comm). This also preserves genetic integrity of individual paddlefish populations which have only recently been demonstrated to be genetically variable and possibly distinctive from each other (Epifanio et al., 1996).

Issues Not Addressed in GBMc Report

In addition to the criteria discussed in the GBMc report, other issues are not addressed which are relevant to fish reproduction in the exclusion zone. These include:

Dredging effects on larval paddlefish – Paddlefish larvae exhibit positive rheotaxis (Adams et al., 1999) and low mortality at comparatively high velocities (e.g., 1.5 m/s) so they may resist entrainment in some swift water habitats (Payne et al., 1990). Paddlefish larvae, however, swim from bottom to surface and glide back to the bottom (Wallus, 1986). This could make larvae susceptible to non-lethal entrainment (and loss). Larvae might also be impacted by turbulence generated by some forms of dredge disposal (Killgore et al., 1987). Direct effects of dredging on paddlefish larvae are ignored.

Changes in substrate composition – Paddlefish adults require coarse substrates for spawning (Crance, 1987) and larvae are known to occur over packed sand (Yeager and Wallus, 1990). Dredging will change substrate composition and distribution within the channel. How this will affect quality and extent of paddlefish spawning grounds is not discussed.

Other sensitive fish species - The special condition of the permit restricting dredging in the exclusion zone is not specific to paddlefish. Other sensitive species inhabit this area of the White River that spawn early in the season (March) and/or require large substrates in which to spawn (gravel, coarse erosional sand). These include: Sabine shiner, western sand darter, crystal darter, and stargazing darter. Impacts of dredging on these species are not addressed. At the 19 Sep 00 meeting, GBMc stated that those species were unlikely to occur in the exclusion zone, that the

White River had been extensively sampled, and there were no records for those species in the exclusion zone. Photocopies of distribution maps from the book "Fishes of Arkansas (Robison and Buchanan, 1988)" were distributed to support this contention. CEWES noted that some sections of the White River were not readily accessible to collectors and that the exclusion zone may not have been sampled adequately to refute or confirm the occurrence of those species. CEWES also noted that three of those species were documented above the exclusion zone in the vicinity of Batesville (Neil Douglas, unpublished data; Robison and Buchanan, 1988), that all species have been documented at or below the mouth of the Black River (in recent surveys by CEWES), and that suitable habitat apparently occurred in between these sites.

Miscellaneous Shortcomings of GBMc Report

1. There is no evidence that primary scientific literature was consulted. The five principal references cited include a USFWS "blue book, " book chapters, and an unpublished report. Several relevant studies of paddlefish reproduction are conspicuously absent (e.g., Purkett, 1961; Pasch et al., 1980, Wallus, 1986; Yeager and Wallus, 1990).

2. Standard citation style is not used. It is impossible to know, for example, the source for the statement that 14 $^{\circ}$ C is optimal for paddlefish spawning.

3. Paddlefish spawning is presumably triggered by concurrent rise in water temperature and river stage, but temperature and hydrographic data presented in report are for two different time periods (1991-1994 and 1997-2000 respectively) and are presented at two vastly different time scales (daily Jan-Dec for period of record and daily Feb-May by year).

4. There is no analysis of data. Report makes generalizations based on inspection of raw data but attempts no quantitative summary of data. Minimally, some univariate analyses should have been provided: e.g., frequency and durations of significant, sustained discharge (value to be objectively determined from literature or stage-duration data). Ideally, bi-variate or multivariate analyses of hydrographic data with or without temperature data should have been attempted to determine what percentage of time favorable conditions prevail during the months of Feb, Mar, Apr, May, and Jun for the period of record.

5. There is an implicit assumption that absence of data (i.e., lack of observations) are equivalent to negative data (e.g., lack of occurrence). For example, the absence of observations of paddlefish in the main channel of the exclusion zone can be directly attributed to several factors including low sampling effort there by AGFC, which concentrated efforts in backwaters, chutes, and downstream reaches (S. Filipek, pers.comm.) and the low number of paddlefish equipped with telemetry devises released nearby (Filipek, 1990).

6. Data are frequently missing, ignored, or mis-cited. For example, hydrographic data are omitted for the years 1987-1990 during which early March discharges were elevated, prolonged, and suitable for paddlefish spawning. Also, presentation of a single multi-year hydrograph obscured small-scale variations in base discharge sufficient for paddlefish incubation (i.e., increases of 2-3 weeks duration). The apparent paucity of paddlefish observations in or near the exclusion zone was exaggerated by the failure to restrict interpretations of telemetry data to only those

fish which could have reasonably moved into the exclusion zone during the spawning season based on time of year, river stage, and longitudinal position in the river. Also, there was no mention in the GBMc report of a sixth paddlefish that occurred near the downstream limit of the exclusion zone (#41.500). Finally, the capture date of a sedentary paddlefish near the downstream limit of the exclusion zone (#41.480) was approximated as mid-March rather than early March.

Conclusions

Spatio–temporal variation in paddlefish responses to environmental cues (e.g., Wallus, 1986) make precise and accurate delineation of spawning and rearing grounds difficult, but based on the criteria established in the GBMc report, the exclusion zone provides suitable spawning habitat. During the period Mar-May of most years, rising water levels in late February or early March coincide with rising water temperature; substrates and depths within the reach are suitable for spawning and rearing.

Conclusions of the GBMc report that regulated water flows from the dams upstream of the exclusion zone render it less suitable for spawning than downstream reaches of the White River and the Black River (p. 5) are not supported by Batesville hydrographic data (see above comments) or by the scientific literature. Previous field studies of paddlefish indicate that discharges 10,000 - 30,000 cfs are suitable for paddlefish reproduction (Russell, 1986), that spawning paddlefish preferentially select a variety of habitats (Southall and Hubert, 1984), with spawning more pervasive (i.e., at a greater number of sites) at higher discharges (Wallus, 1986). Therefore, when peak discharges occur in early March, fish would be just as likely to move into the White River exclusion zone as the Black River or downstream (The differences in water temperature between the exclusion zone and the Black River, discussed in the GBMc report, are so negligible as to be within the range of sampling error and small-scale spatial variability). In fact, the large numbers of paddlefish collected in channel scars and chutes in the exclusion zone (S. Filipek, pers.comm.) indicate that paddlefish occur throughout this reach and would support the contention that paddlefish are spawning in that reach.

Individual paddlefish spawning periods are typically brief, but the range of reported water temperatures is relatively broad and timing can vary substantially. Also, multiple spawnings can take place within a single reproductive period, if multiple hydrographic peaks occur, although a relatively low percentage of females reproduce during any single year. Consequently, it is conservative to assume a wide calendar season for paddlefish reproduction and it is prudent to maintain a wide window (i.e., Mar-May) of prohibited dredging in the exclusion zone of the White River.

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WRAP 01-02

ERDC-WES-EL 10 Apr 2002

WRAP RESPONSE

Mobley Construction and Mining Impacts to Fishes in the White River, AR: Evaluation of GBMc Comments on WRAP Responses #01-02 and #01-03

Background

The US Army Army Engineer, Memphis District (CEMVM) has imposed special conditions on a dredging permit issued to Mobley Construction for the removal of sediments from the White River, AR. Specifically, Mobley Construction is prohibited from dredging in the reach from Rivermile (RM) 259 (at the mouth of the Black River near Jacksonport, AR) to RM 274 (Near Oil Trough, AR) during the period March-May. This area, referred to as the "exclusion zone," is believed to be an important spawning ground for paddlefish (*Polyodon spathula*) and for several other species of concern in the state of Arkansas.

An environmental consultant for Mobley, GBMc, prepared a report (dated 09 Aug 2000) that attempted to refute environmental concerns regarding paddlefish spawning. Main points of the GBMc report were: i) hydrology and water temperature during the March-May period were sub-optimal for paddlefish spawning, principally because of the discharges of dams upstream; ii) no empirical evidence existed showing that paddlefish spawn in the exclusion zone; iii) suitable habitat exists elsewhere in the White River; iv) the paddlefish population is not in jeopardy, as indicated by lack of federal status, commercial fishing activity, and persistence after more than 60 years of dredging by Mobley Construction.

CEMVM subsequently requested technical assistance from fish biologists at the U.S. Army Engineer Research and Development Center (ERDC) at Waterways Experiment Station (WES). Under the WRAP, Jan Hoover: i) attended a meeting of Mobley Construction, GBMc, and CEMVM to review concerns and positions of all parties; ii) reviewed primary scientific literature on paddlefish biology and wrote a formal evaluation of the Mobley/GBMc position on the likelihood of mining-related impacts to paddlefish; iii) with Jack Killgore and Steven George (WES), Neil Douglas (University of Louisiana at Monroe), Judy DeLoach (CEMVM), conducted field surveys of fishes and physical habitat in the exclusion zone; iv) reviewed literature and wrote a formal evaluation of possible mining-related impacts on fishes other than paddlefish. Conclusions were that environmental conditions in the exclusion zone were suitable for the support and spawning of paddlefish (WRAP Response #01-02; dated 15 Dec 2000) and other species of concern (WRAP Response #01-03; dated 21 Dec 2000), and that the special conditions of the permit were justified.

Those species and their conservation status are:

Common name, scientific name	Arkansas Natural Heritage Commission	American Fisheries Society (Warren et al., 2000)
Paddlefish, *Polyodon spathula*	Inventory element	Vulnerable
Sabine shiner, *Notropis sabinae*	Inventory element	Currently stable
Pealip shorthead redhorse, *Moxostoma macrolepidotum pisolabrum*	Inventory element	Currently stable
Western sand darter, *Ammocrypta clara*	Inventory element	Vulnerable
Crystal darter, *Crystallaria asprella*	Inventory element	Vulnerable
Stargazing darter (*Percina uranidea*)	Under review	Vulnerable

GBMc wrote comments to those responses attempting to refute the conclusions of the WRAP responses (dated 20 Mar 2001). Comments were based on a "review" of some references cited in the original WES literature review.

CEMVM requested technical assistance again through the WRAP in February of this year. We have now reviewed the GBMc comments, re-examined the literature, communicated with several of the paddlefish biologists whose work is being discussed, and have compiled data from primary literature sources (Tables 1-4, attached). Our position is unchanged. Permit restrictions imposed on Mobley Construction via special conditions imposed by CEMVM are environmentally conservative and reasonable based on "best available information." Five species of concern are known to occur in the exclusion zone (Note - We were unable to confirm the occurrence of the Sabine shiner; we did not sample for paddlefish since their occurrence in this reach is uncontested) and habitat conditions there are suitable (even if sub-optimal) for spawning and rearing. Temporal restrictions on dredging (March through May) are also well-justified based on the documented onset of paddlefish spawning at this latitude. Approximately half of the populations studied from Latitude 34 ° N to 38 ° N were documented to spawn in March (Table 1). It is also justified based on documented occurrences and on spawning seasons and/or habitat requirements of four other fish species listed as inventory elements by the Arkansas Natural Heritage Commission: pealip shorthead redhorse, western sand darter, crystal darter, and stargazing darter. Redress of specific comments by GBMc (2001) follow.

In the sections that follow, blocks of text in boldface and inside quotation marks are extracted from the GBMc responses to the WRAP reports prepared by Jan Hoover (WES) in 2000 (#01-02, 01-03). Text in standard type and not inside quotation marks are replies to the GBMc reponses.

WRAP Response 01-02 [Paddlefish]:
GBMc Conclusions (p.10)

"Although attempts have been made to collect and identify spawning locals [sic] in the White River, observations of spawning, eggs, larvae, or young-of-year paddlefish have not been identified, in the reach of White River which Mobley is being denied...."

Other than a single study of adult movements in the White River (Filipek, 1990), we are unaware of any special attempts to identify spawning localities in this reach, and none have been made by the Arkansas Game and Fish Commission (Filipek, pers.comm.). Paddlefish spawning activity is notoriously brief (and rarely witnessed), and documentation of early life history stages of paddlefish is rare. They are unlikely to be encountered during routine fish sampling as exemplified by the very noteworthy captures of young-of year throughout history (Hoover et al., 2000). Even those field studies specifically targeting early life history stages of paddlefish typically have small sample sizes (e.g., Houser and Bross, 1959; Pasch et al., 1980; Hoyt, 1984) or employed extended sampling over a large geographic area (e.g., multiple drainages) and a prolonged period of time (e.g., 10 years) to obtain a statistically robust sample (Wallus, 1983). Without appropriate field effort, lack of documentation here does not necessarily indicate lack of occurrence.

"Mobley's proposed activities in the exclusion zone are not likely to have significant adverse impact on the continuation of the species...There is limited potential for far afield adverse impacts to the paddlefish or other fish species...in fact, the paddlefish population (the best in the state) has been maintained in conjunction with Mobley's historical dredging activities since 1934."

Dredging will threaten the White River population of paddlefish, not the species, therefore "continuation of the species" is not an issue. Variability in habitats among populations indicate the need for managing paddlefish at local, not global levels. Genetic studies of the species also emphasize the need for conservation at local levels, specifically protection of individuals and populations and preservation of migration routes and spawning grounds (Epifanio et al., 1996). Mining of stream substrates, in fact, can degrade aquatic environments and impact communities several kilometers downstream of dredging sites (e.g., Brown et al., 1998). Other than highly speculative and anecdotal observations, there are no data indicating that Mobley's dredging has not impacted paddlefish populations in the White River. This would require demographic data collected prior to 1934 (and none has been presented). It is unclear in what way the White River population is "the best in the state," but the only available field study of White River paddlefish indicates that in any given age group, fish are smaller and slimmer than their counterparts in other streams (Filipek, 1990). Slow growth of a famously fast-growing species (Table 1) and low condition of a frequently fat fish (Table 2; also see photographs in Stockard, 1907) do not support the contention that this is an unimpacted population.

"...paddlefish...are not endangered, threatened or candidate species under the Endangered Species Act (ESA)...there is a commercial season on White River paddlefish...the paddlefish is not a "data element" in either Jackson or Independence County."

Federal listing is not a requirement for permit consideration. Paddlefish are listed as "inventory elements" (equivalent to species of special concern) by the Arkansas Natural Heritage Commission meaning they are "sensitive" or of "conservation concern (Cindy Osborne, pers.comm.)." They are listed as "vulnerable" by the American Fisheries Society (Warren et al., 2000). Such classifications by regional entities (e.g., Arkansas) or scientific groups (e.g., American Fisheries Society) may be used when evaluating permit applications. The existence of a commercial season does not indicate an unimpacted population, since commercial fishing removes adult and sub-adult fishes, other factors may impact early life history stages. Paddlefish not appearing as "data elements" for any individual county cannot be construed as meaning that the species is not of special concern there, since a species is listed only if there is a record of it for that county (Cindy Osborne, pers.comm..). Lack of documentation here does not necessarily indicate lack of occurrence.

"...paddlefish may have been collected within the exclusion zone, none of those were found to utilize the area for reproduction."

There have been no field studies conducted of paddlefish reproduction in this section of the White River. Lack of documentation here does not necessarily indicate lack of occurrence. Physical habitat features are conducive for paddlefish spawning.

"....Exclusion zone and area of proposed activity represents a small fraction of habitat available in the 34 mile reach of the White River from Newport to Batesville."

No data on habitat quality (bathymetry, hydraulics, substrate) or extent are provided to support this contention.

GBMc Comments on Paddlefish

The nine pages of comments are principally reiterations of GBMc positions stated in the Conclusions of this or their original report (09 Aug 2000) with some attempt at support from references listed in the WRAP reports. They will not be addressed here. A few comments, however, merit some clarification. Specifically -

p. 4 – "...information does not support the WRAP's authors [sic] interpretation that spawning temperature of 10 ° C and that incubation temperature of 8 ° C are sufficient to support successful [emphasis added] spawning and larval development."

Incorrect. Firstly – The statement referred to the HSI models invoked by GBMc. The statement was: "These models also indicate that 'optimal' temperatures do not have to be continuously 'maintained' to insure successful hatching and survival, only that a temperature range be maintained above some minimal value (e.g., 8 °C)." Those models (Crance, 1987 – p. 127 – Fig.4) clearly show a narrower range of suitable (HSI > 0.00) temperatures for spawning (approx 10–23 °C), than for egg incubation (approximately 6-26 °C), and early larval survival (approximately 7-32 °C). The "interpretation," here, is logic. If eggs incubate and larvae survive at lower temperatures than at which they were spawned, it is not necessary that minimal spawning temperatures be maintained for successful, albeit if sub-optimal (HSI = 1.00) spawning. The models, not the WRAP author, indicated that paddlefish eggs spawned at 10-12 °C can suitably incubate at a temperature of 8 °C.

Secondly - Temporal trends in the onset of fish reproduction follow latitudinal gradients. The reason is that patterns of sunlight and air temperature vary along latitudinal gradients and those are the exogenous factors associated with gonadal maturation, and other endogenous changes associated with reproduction. Paddlefish spawning in the White River has not been directly observed, but an estimate of the onset of the season can be obtained objectively by looking at latitudinal variation in paddlefish spawning seasons. We have compiled information from our files (Table 3) and we invite others to supplement it. There is a clear trend for earlier spawning at lower latitudes: Feb at < 30 ° N (1/1 study), March at 31-38 ° N (10/16 studies), April and May at 41-42 ° N (3/3 studies), and June at > 45 ° N (1/1 study). The White River exclusion zone occurs at 35.6 ° N. There are eight relevant studies conducted within 1.5 ° latitude of this. Of those 8 studies, five indicate a March onset of spawning. Four of these studies provide some kind of data on water temperature, all of which suggest spawning or spawning migrations occur at temperatures of 6-12 °C. The median temperature for this range would be 9 °C.

p.7 - "...preliminary indication that the Arkansas and Osage River populations...are sufficiently divergent from the rest of the Mississippi River populations to warrant separate consideration...WRAP is a misinterpretation of the findings of Epifanio et al., 1996...there does not appear to be a distinctive White River paddlefish population nor can there be based on this research because paddlefish from the White River were MIXED [emphasis added} with Arkansas River paddlefish."

Labeling this as a "misinterpretation" is in fact a "misinterpretation." Firstly, specimens in the Epifanio et al. (1996) study were not "MIXED," data from individuals were pooled. Mixing would obscure differences among sites, pooling allows for evaluation of between site differences (which, according to the authors, was biologically insignificant or undetectable). Authors discuss this at length and it seems apparent from the allele frequency data in the paper.

Secondly, the purposes of the study were to determine whether paddlefish constituted a single, randomly breeding population across its extant distribution (which they did not) and to indicate whether populations have restricted gene flow (which they apparently do) at broad geographic/watershed scales. The authors admit that their sample sizes were small making it difficult to definitively identify distinctive populations or clusters of populations at a sufficiently fine scale to be answered definitively here. The possibility, however, of a distinctive White-Arkansas River population is suggested by three lines of evidence: i) high degree of homozygosity (see Epifanio et al., 1996 – Table 2); ii) an unusual mtDNA haplotype (Epifanio et al., Table 7 – 3/73) unique to the region; iii) the occurrence of three rare nuclear alleles (Epifanio et al., Table 2).

Lastly, the conclusion regarding the separate consideration of the White-Arkansas River paddlefish population was not part of a "misinterpretation." It was an informed statement made by the geneticists in the concluding paragraph of their paper: Geographic variation of paddlefish allozymes and mitochondrial DNA, by John Epifanio and co-workers (Epifanio et al., 1996).

Dr. Epifanio recently told us that mtDNA analyses did not include any specimens from the White River proper, but that because the Arkansas and Lower Missouri Rivers (including the White) displayed the BAA genotype, it indicated a divergent set of populations for the region (pers.comm.). He also stated that there is no "a priori reason to believe that the White River populations would be more like the Mississippi River populations than the rest of the Arkansas or Lower Missouri River populations…until more definitive information could be gathered about the patterns of divergence and genetic relatedness could be established, the "needle on the meter" was pointing toward unique populations."

p.8 – "The flow graphs represented the period 1991-1994 (not 1997-2000 as indicated in the WRAP response). The rationale was to provide the latest data record for the Batesville gage for the same length of time as the water temperature data."

Correct – Our mistake. Statement read: "…temperature and hydrographic data are for different time periods (1991-1994 and 1997-2000 respectively)…" but should have read "….hydrographic data and temperature are for different time periods (1991-1994 and 1997-2000 respectively)…" We apologize for any misunderstanding. Original criticisms of the GBMc report, however, regarding the non-comparable time scales for the two types of data, the difficulty of determining seasonal trends from a single multiple-year hydrograph, and the subjective exclusion of 1987-1990 hydrographs with their elevated discharges in March all stand.

p. 9 - "…mortality rates were from population studies in the southern Alabama River…Atchafalaya River…and Lake Ponctohartrain [sic] in Louisiana…there are significant differences between those waterbodies and the White River…author of WRAP Response appears to be making some broad assumptive statements regarding the general biology of the paddlefish without any evidence that they are relevant to the White River population."

Only partly correct - Those waters are different from the White River, and we were making a broad statement about paddlefish biology. However, there is plenty of "evidence" to support us so "assumptive statements" are not the case here. Until the early 1980s, there were virtually no data for paddlefish mortality rates. Since then, data have been surprising and consistent (Table 4). Mortality of adults and subadults is high, ranging from 15-48%. This should be a source of concern since it is documented for a large, long-lived animal with few natural enemies. Although, two estimates of natural mortality (exclusive of fishing) were comparatively low at < 9 % (Boone and Timmons, 1995) and 11% (Rosen et al., 1982); other studies conducted in areas with no fishing or with harvest moratoria are > 25% (Reed et al., 1992; Paukert 1998). Add to this the possibility of high larval mortality from natural or anthropogenic hydraulic variation (Table 4), and the vulnerability of individual paddlefish populations becomes obvious and troubling.

WRAP Response 01-03 [Sensitive Fish Species]: GBMc Conclusions (p.14)

Note – Four collections of fish made in the exclusion zone in October 2000 documented 30 species of fish (Table 5). Three of these are inventory elements for the state of Arkansas: pealip shorthead redhorse, western sand darter, crystal darter. One is proposed for listing as an inventory element: stargazing darter.

"None of the species...are federally listed T & E species or even candidates for listing."

Federal listing is not a pre-requisite for imposing restrictions on dredging, but "best available information" is. The "best available information" indicates that all five species are imperiled at a regional or national level and warrant some level of protection. Four of the five species are listed by the Arkansas Natural Heritage Commission as "inventory elements" equivalent to "special concern" status; the fifth is under review. Three of the five species are listed as "vulnerable" by the American Fisheries Society (Warren et al., 2000).

"...displacement will be confined to the immediate vicinity of operations with limited far-field effects."

No information is provided that would support this statement. Aquatic habitats, invertebrates, and fishes can be altered over distances of kilometers upstream and downstream of mining sites (Brown et al., 1998). Changes in stream morphometry (geomorphology) of the altered gravel bar could persist for years, possibly decades.

"Each of the species...have established populations in other streams in Arkansas...Mobley's activities will have no effect on the populations present in those streams. "

Impacts to a species are relative (based on the number and distribution of populations), but impacts to a population are absolute. Mobley's activities pose potential impacts to the White River populations.

"The potential impact that the proposed activity would have on the continuance of each of the "species of special concern" is negligible..."

See above. Impacts on the "continuance of the species" are not an issue; impacts on populations are.

GBMc Comments on Sensitive Species

p. 12-13 - Each of the five species accounts written by GBMc documents geographic distribution outside the White River, notes that activities will be confined to the White River, and concludes with a statement to the effect that potential impact of the proposed activity on the continuance of the species is negligible due to limited activities in the exclusion zone, and presence of established populations elsewhere.

An interesting, but hardly novel concept – relying on other populations (and other people) for the "continuance of the species." It did not work for such widespread and abundant species as the American bison, the passenger pigeon, or the harelip sucker. The five species in question are not sufficiently imperiled to be federally listed, but to write off local populations is not environmentally prudent.

First, some of these species may have moderately broad geographic distributions but they are not broadly distributed throughout the White River system. Impacts that occur to the population will be substantial if those species do not occur commonly outside the exclusion zone. GBMc does not provide data to indicate that any of these species are broadly distributed throughout the White River, but historical data suggest that three species are relatively uncommon in the lower reaches of the White River: Sabine shiner, stargazing darter, and western sand darter. Of these species, the geographic range of the stargazing darter is contained almost entirely within the state of Arkansas and should be of particular concern since populations in other states have been extirpated (Robison and Buchanan, 1988). The pealip shorthead redhorse, although broadly distributed throughout the White River, is also geographically restricted, found only in the White and Arkansas Rivers in Arkansas (and the Red River in Oklahoma).

Records for White River Inventory Elements, Robison and Buchanan 1988.		
Common name, scientific name	Number of Records in Upper White River and Black River Systems	Number of Records in Below the Black River
Paddlefish, *Polyodon spathula*	5	10
Sabine shiner, *Notropis sabinae*	16	1
Pealip shorthead redhorse, *Moxostoma macrolepidotum pisolabrum*	4	4
Western sand darter, *Ammocrypta clara*	10	5
Crystal darter, *Crystallaria asprella*	4	4
Stargazing darter (*Percina uranidea*)	13	1

Secondly – species, even endangered species, are usually managed at the population level. This is done partly to preserve genetic integrity of local populations, partly to account for regional variation in abundance, habitat preferences, etc.. Thirdly – Mobley's activities in the exclusion zone may be "limited," but if they take place nearshore where most small fish species occur (instead of the thalweg), or during the early spring (when some of the species are spawning), or if they substantially alter composition of sediments (required by darters), the White River populations will be impacted.

Summary

All available information from the scientific literature, and from information on the White River, indicate that the special conditions of the permit issued to Mobley Construction are reasonable and justified. Specifically:

i) Paddlefish occur in the exclusion zone, and hydrographic pulses and water temperatures in late winter-spring are comparable to those associated with paddlefish spawning elsewhere thereby justifying the designation of the exclusion zone based on habitat (WRAP #01-02).

ii) Paddlefish populations at the approximate latitude of the exclusion zone begin spawning in March thereby justifying prohibition of dredging during the period Mar-June (Table 1).

iii) Four other benthic species of fishes listed as "inventory elements" or under review for listing as such by the Arkansas Natural Heritage Commission are known to inhabit the exclusion zone, utilize sand and gravel substrates, and three of these spawn in spring, thereby providing additional rationale for special conditions of the permit.

Recommendation

To date, literature review and field data relevant to this permit have been provided by the Arkansas Game and Fish Commission and the US Army Corps of Engineers. Because Mobley Construction seeks to exploit a public resource (i.e., White River) for personal profit and at the risk of impacting five fish populations identified as inventory elements by the state of Arkansas (six, if the Sabine shiner occurs in the exclusion zone), it should be incumbent on Mobley Construction to provide additional information to address concerns and prompt re-consideration of the special conditions of that permit.

Mobley and GBMc contend that since there are no empirical data showing that paddlefish spawn in the exclusion zone, and since suitable habitat is available elsewhere, that paddlefish and the other species are just as likely to spawn in other locations (e.g., in the Black River) but offer no supporting data for this contention. Clearly, the only way this issue will be resolved to the satisfaction of all parties is with a rigorous, site-specific, well-designed field study of dredging-related impacts to those fishes and their spawning habitats. We recommend that Mobley Construction fund an independent researcher (or group of researchers) to conduct such a study. Input on the design of such a study should be solicited from and approved by qualified representatives from all affected agencies: CEMVM, ERDC (WES), and AGFC. Scope of study should include immediate and longer-term (1-2 years) effects of mining on water quality, stream hydraulics and geomorphology, substrate composition, paddlefish movements, paddlefish spawning and rearing, occurrence and spawning of other sensitive species

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WRAP RESPONSE # 01-03: Dredging Permit for Mobley Construction Company In the White River, Arkansas: Sensitive Fish Species in the Exclusion Zone

Background

Mobley Construction Company has requested a dredging permit from the US Army Engineer Memphis District to mine sand from the White River channel above the mouth of the Black River. Memphis District, however, attached a special condition to the permit that prohibits dredging in a reach extending from Rivermile 259 (at the mouth of the Black River near Jacksonport, Arkansas) to Rivermile 274 (near Oil Trough, Arkansas) during the period March-May. This "exclusion zone" was established for this period to protect spawning and rearing grounds of environmentally sensitive fishes that reproduce in swift water habitats early in the fish reproductive season. These fishes include the paddlefish (*Polyodon spathula*), addressed in a separate report, and four species of small, littoral fishes.

These species and their conservation status are:

Common name, scientific name	Arkansas Natural Heritage Commission	American Fisheries Society (Warren et al., 2000)
Sabine shiner, *Notropis sabinae*	Inventory element	Currently stable
Western sand darter, *Ammocrypta clara*	Inventory element	Vulnerable
Crystal darter, *Crystallaria asprella*	Inventory element	Vulnerable
Stargazing darter (*Percina uranidea*)	Under review	Vulnerable

The Arkansas Natural Heritage Commission (ANHC) use of "inventory element" is equivalent to "special concern" status of other agencies; the stargazing darter is currently under review for addition to the Arkansas list (Cindy Osborne, ANHC, pers.comm.). The American Fisheries Society designation of "vulnerable" indicates a species or subspecies that may become endangered or threatened by relatively minor disturbances to its habitat or that deserves monitoring of its distribution and abundance in continental waters of the United States to determine its status (Warren et al., 2000)."

On 19 Sep 00, a meeting was held among representatives from Mobley Construction Company and its consultant GBMc and Associates (GBMc), Memphis District (CEMVM), and the US Army Engineer Research and Development Center at Waterways Experiment Station (CEWES). Attendees were Bryce Mobley and Phyllis Hardin (Mobley Construction Company), Roland McDaniel (GBMc), Judy O. DeLoach, Patricia Jones, Linda Boyd, Larry Watson, and Colonel Kreuger (CEMVM), and Jan Jeffrey Hoover (CEWES). Primary purpose of the meeting was to summarize and discuss findings of a report by GBMc on suitability of the exclusion zone as paddlefish spawning and rearing habitat. Secondarily, the suitability of the exclusion zone as habitat for these four other sensitive species was discussed.

GBMc stated that those species were unlikely to occur in the exclusion zone, that the White River had been extensively sampled and there were no records for those species. Photocopies of distribution maps from the book "Fishes of Arkansas (Robison and Buchanan, 1988)" were distributed to support this contention. CEWES noted that some sections of the White River were not readily accessible to collectors and that the exclusion zone may not have been sampled adequately to refute or confirm the occurrence of those species. CEWES also noted that all four species have been collected in the White River downstream from the exclusion zone, between RM 247 and RM 259 (CEWES, unpublished data), and all but the crystal darter have been collected in the White River near Batesville, RM 295 (Neil Douglas, unpublished data; Robison and Buchanan, 1988). This distribution, and the presence of shallow, swiftwater habitat and coarse erosional substrates, would strongly indicate that those species should also occur in the exclusion zone. GBMc and Mobley Construction Company did not accept this possibility and indicated that empirical data were required to confirm occurrence in the exclusion zone and, by that fact, the risk of dredging related impacts to those species.

Approach

A field study was conducted 11-12 Oct 2000 to characterize physical habitats in the exclusion zone and to ascertain presence of the sensitive species identified by the ANHC. Data on physical habitat and fishes were collected from four stations in the exclusion zone, three of which are sites which Mobley Construction Company proposes to dredge: RM 262 (2 mi W of Jacksonport, AR); RM 262.3 (downstream edge of Craven's Chute); RM 269.3 (Hulsey Bend); RM 273.2 (Pleasant Island). Stream width was measured from water's edge to water's edge using a LASER rangefinder. Water velocity and depth were measured at 10 approximately equi-distant points along a cross-sectional transect. Water temperature, specific conductance, dissolved oxygen, and pH were recorded with a Hydrolab multi-parameter water quality probe. Turbidity was measured with a Hach 2100P turbidimeter. Dominant substrates were classified qualitatively and recorded. Fishes were collected using standard effort employed in previous studies of White River fishes by CEWES: 5 hauls with a 8 ft X 20 ft, 3/16 inch mesh seine. Additional fishes were obtained by subsequent non-quantitative seining. All fish were preserved in 10% formalin. In the laboratory, fishes were washed, sorted, enumerated, and identified to species according to Douglas (1974) and Robison and Buchanan (1988).

Habitat and Sensitive Fishes in the White River Exclusion Zone

Physical habitat was similar among sites (Table 1). Water was cool (17 – 19 ° C), moderately conductive (approximately 340 umhos/cm), well-oxygenated (approximately 12 mg/l), alkaline (approximate pH = 9.2), and clear (< 7 NTU). Maximum velocity was 67-77 cm/s and gravel was the dominant substrate with varying amounts of sand. Stream width was 303-336 ft except at Pleasant Island where it was over 1000 ft.

Table 1. Physical habitat in the White River exclusion zone, 11-12 Oct 2000.

Parameter	RM 262	RM 262.3	RM 269.3	RM 273.2
Water temperature ($^{\circ}$C)	18.9	17.8	17.2	17.5
Conductance (umhos/cm)	348	342	339	344
Dissolved oxygen (mg/l)	11.9	12.1	11.9	11.6
PH	9.2	9.2	9.3	9.3
Turbidity (NTU)	4.8	6.4	2.9	3.4
Maximum depth (ft)	6.4	10.7	4.0	5.6
Maximum velocity (cm/s)	77	71	67	76
Stream width (ft)	309	336	303	1110
1 $^{\circ}$ and 2 $^{\circ}$ substrate	Gravel-sand	Gravel-sand	Gravel-sand	Gravel-sand

Thirty species of fish were collected (Table 2). Fish community was dominated taxonomically by minnows (12 species) and darters (9 species). Community was dominated numerically by three species of shiner characteristic of White River fish assemblages: mimic shiner, *Notropis volucellus,* blacktail shiner, *Cyprinella venusta* , and telescope shiner, *Notropis telescopus*. The Sabine shiner was not collected but is likely to occur based on its previously documented occurrence at RM 257.5 and RM 259 (CEWES unpublished data). Other sensitive fish species were collected at all four sites. Western sand darters were collected at RM 262.3, crystal darters at RM 262 and RM 269.3, and stargazing darters at RM 269.3 and 273.2. Additionally, another species listed as an inventory element by the ANHC was collected: the pealip shorthead redhorse, *Moxostoma macrolepidotum pisolabrum*, at RM 273.2. It may not have been included in the ANHC list of sensitive species for this part of the White River due to the paucity of records for this species in this region (Robison and Buchanan, 1988).

Habitat and Reproduction of Sensitive Fish Species in the White River Exclusion Zone

All five species listed by the ANHC occur over coarse substrates and most are early spawners (Kuehne and Barbour, 1983; Page, 1983; Robison and Buchanan, 1988). In Arkansas, distributions are spotty. The Sabine shiner is a bottom dwelling minnow that occurs over silt-free sand. Spawning commences during high water in early spring; gonads begin to mature in March and spawning begins in early April (Heins, 1981). Like other members of the longnose shiner (*Notropis longirostris*) species group, it is a species associate of the sand darters (*Ammocrypta* spp.)(Hubbs and Walker, 1942, Heins and Clemmer, 1975; Heins et al., 1980; Heins, 1981). The shorthead redhorse is found over gravelly bottoms and begins spawning in late April. The western sand darter inhabits sandy substrates, in which it buries itself. Spawning season is not documented but it is presumed to spawn in June. The crystal darter is also found in sand or in fine gravel. It has a protracted spawning season with peak reproductive activity in February and March (George et al., 1996), but many aspects of its biology are unknown due to the specialized field techniques required to collect it (Katula, 2000). It is vulnerable to habitat alterations such as dredging and numbers are declining over much of its range. Kuehne and Barbour (1983) state: "The crystal darter continues to lose ground in the battle for survival partly due to dredging operations and losses of extensive areas of clean sand." The stargazing darter occurs on gravel bottoms and is intolerant of silt. Reproductive season is unknown. This species has been extirpated in several areas including the lower Wabash River and the states of Indiana and Illinois, so that its range now lies mostly within the state of Arkansas (Robison and Buchanan, 1988; Page and Burr, 1991).

Table 2. Fishes of the White River collected between Jacksonport and Oil Trough, Arkansas, 11-12 Oct, 2000. Numbers represent total number collected in a standard effort (5 hauls with a 20-ft. seine). A "+" indicates a species collected during supplemental sampling. Taxa with an asterisk are listed as species of special concern by the Arkansas Natural Heritage Commission. Those with a double asterisk are under consideration for listing.

Common name, scientific name	Rivermile				
	262	262.3	269.3	273.2	Total
Cyprinidae, minnows and carps					
Campostoma anomalum, central stoneroller	+			1	1
Cyprinella galactura, whitetail shiner	1			1	2
Cyprinella venusta, blacktail shiner	250	44	2	107	403
Erimystax x-punctatus, gravel chub	2			5	7
Hybognathus nuchalis, MS. silvery minnow	34	1			35
Macrhybopsis aestivalis, speckled chub	2	6	4		12
Notropis atherinoides, emerald shiner		2			2
Notropis rubellus, rosyface shiner	2		2	52	62
Notropis telescopus, telescope shiner	63	2	3	94	162
Notropis volucellus, mimic shiner	291	34	5	76	406
Pimephales notatus, bluntnose shiner				2	2
Pimephales vigilax, bullhead minnow	53	36		1	90
Catostomidae, suckers					
Carpiodes carpio, river carpsucker	2				2
Hypentelium nigricans, northern hog sucker	1	1		2	4
Moxostoma erythrurum, golden redhorse	31	11		22	64
Moxostoma macrolepidotum pisolabrum, pealip shorthead redhorse *				1	1
Ictaluridae, catfishes					
Ictalurus punctatus, channel catfish	1				1
Atherinidae, silversides					
Labidesthes sicculus, brook silverside	1				1
Poeciliidae, livebearers					
Gambusia affinis, western mosquitofish	2	1			1
Centrarchidae, sunfishes & black basses					
Micropterus dolomieui, smallmouth bass	1				1
Micropterus punctulatus, spotted bass		+			+

Percidae, darters					
Ammocrypta clara, western sand darter *		9			9
Ammocrypta vivax, scaly sand darter	2				2
Crystallaria asprella, crystal darter *	6		2		8
Etheostoma blennioides, greenside darter				1	1
Etheostoma caeruleum, rainbow darter				4	4
Etheostoma stigmaeum, speckled darter	+	2			2
Percina evides, gilt darter			3	5	8
Percina uranidea, stargazing darter **			11	3	14
Percina vigil, saddleback darter	3	13	6		22
Total number of species	748	168	38	377	1331
Total number of fish	19	14	9	16	30

Conclusions

Four benthic species of fish, occurring in the White River exclusion zone and listed as inventory elements by the ANHC, are dependent on gravel and sand substrates, making them directly vulnerable to dredging operations. Mining gravel-sand substrates from the river bottom would entrain these species, some during their spawning season. Net loss of sand from that reach would constitute habitat losses for all species, but particularly so for sand darters and crystal darters (and Sabine shiners should they occur there).

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WRAP 01-03

ERDC-WES-EL

10 Apr 2002

WRAP RESPONSE
Mobley Construction and Mining Impacts to Fishes in the White River, AR: Evaluation of GBMc Comments on WRAP Responses #01-02 and #01-03

Background

The US Army Army Engineer, Memphis District (CEMVM) has imposed special conditions on a dredging permit issued to Mobley Construction for the removal of sediments from the White River, AR. Specifically, Mobley Construction is prohibited from dredging in the reach from Rivermile (RM) 259 (at the mouth of the Black River near Jacksonport, AR) to RM 274 (Near Oil Trough, AR) during the period March-May. This area, referred to as the "exclusion zone," is believed to be an important spawning ground for paddlefish (*Polyodon spathula*) and for several other species of concern in the state of Arkansas.

An environmental consultant for Mobley, GBMc, prepared a report (dated 09 Aug 2000) that attempted to refute environmental concerns regarding paddlefish spawning. Main points of the GBMc report were: i) hydrology and water temperature during the March-May period were sub-optimal for paddlefish spawning, principally because of the discharges of dams upstream; ii) no empirical evidence existed showing that paddlefish spawn in the exclusion zone; iii) suitable habitat exists elsewhere in the White River; iv) the paddlefish population is not in jeopardy, as indicated by lack of federal status, commercial fishing activity, and persistence after more than 60 years of dredging by Mobley Construction.

CEMVM subsequently requested technical assistance from fish biologists at the U.S. Army Engineer Research and Development Center (ERDC) at Waterways Experiment Station (WES). Under the WRAP, Jan Hoover: i) attended a meeting of Mobley Construction, GBMc, and CEMVM to review concerns and positions of all parties; ii) reviewed primary scientific literature on paddlefish biology and wrote a formal evaluation of the Mobley/GBMc position on the likelihood of mining-related impacts to paddlefish; iii) with Jack Killgore and Steven George (WES), Neil Douglas (University of Louisiana at Monroe), Judy DeLoach (CEMVM), conducted field surveys of fishes and physical habitat in the exclusion zone; iv) reviewed literature and wrote a formal evaluation of possible mining-related impacts on fishes other than paddlefish. Conclusions were that environmental conditions in the exclusion zone were suitable for the support and spawning of paddlefish (WRAP Response #01-02; dated 15 Dec 2000) and other species of concern (WRAP Response #01-03; dated 21 Dec 2000), and that the special conditions of the permit were justified.

Those species and their conservation status are:

Common name, scientific name	Arkansas Natural Heritage Commission	American Fisheries Society (Warren et al., 2000)
Paddlefish, *Polyodon spathula*	Inventory element	Vulnerable
Sabine shiner, *Notropis sabinae*	Inventory element	Currently stable
Pealip shorthead redhorse, *Moxostoma macrolepidotum pisolabrum*	Inventory element	Currently stable
Western sand darter, *Ammocrypta clara*	Inventory element	Vulnerable
Crystal darter, *Crystallaria asprella*	Inventory element	Vulnerable
Stargazing darter (*Percina uranidea*)	Under review	Vulnerable

GBMc wrote comments to those responses attempting to refute the conclusions of the WRAP responses (dated 20 Mar 2001). Comments were based on a "review" of some references cited in the original WES literature review.

CEMVM requested technical assistance again through the WRAP in February of this year. We have now reviewed the GBMc comments, re-examined the literature, communicated with several of the paddlefish biologists whose work is being discussed, and have compiled data from primary literature sources (Tables 1-4, attached). Our position is unchanged. Permit restrictions imposed on Mobley Construction via special conditions imposed by CEMVM are environmentally conservative and reasonable based on "best available information." Five species of concern are known to occur in the exclusion zone (Note - We were unable to confirm the occurrence of the Sabine shiner; we did not sample for paddlefish since their occurrence in this reach is uncontested) and habitat conditions there are suitable (even if sub-optimal) for spawning and rearing. Temporal restrictions on dredging (March through May) are also well-justified based on the documented onset of paddlefish spawning at this latitude. Approximately half of the populations studied from Latitude 34 ° N to 38 ° N were documented to spawn in March (Table 1). It is also justified based on documented occurrences and on spawning seasons and/or habitat requirements of four other fish species listed as inventory elements by the Arkansas Natural Heritage Commission: pealip shorthead redhorse, western sand darter, crystal darter, and stargazing darter. Redress of specific comments by GBMc (2001) follow.

In the sections that follow, blocks of text in boldface and inside quotation marks are extracted from the GBMc responses to the WRAP reports prepared by Jan Hoover (WES) in 2000 (#01-02, 01-03). Text in standard type and not inside quotation marks are replies to the GBMc reponses.

WRAP Response 01-02 [Paddlefish]:
GBMc Conclusions (p.10)

"Although attempts have been made to collect and identify spawning locals [sic] in the White River, observations of spawning, eggs, larvae, or young-of-year paddlefish have not been identified, in the reach of White River which Mobley is being denied…."

Other than a single study of adult movements in the White River (Filipek, 1990), we are unaware of any special attempts to identify spawning localities in this reach, and none have been made by the Arkansas Game and Fish Commission (Filipek, pers.comm.). Paddlefish spawning activity is notoriously brief (and rarely witnessed), and documentation of early life history stages of paddlefish is rare. They are unlikely to be encountered during routine fish sampling as exemplified by the very noteworthy captures of young-of year throughout history (Hoover et al., 2000). Even those field studies specifically targeting early life history stages of paddlefish typically have small sample sizes (e.g., Houser and Bross, 1959; Pasch et al., 1980; Hoyt, 1984) or employed extended sampling over a large geographic area (e.g., multiple drainages) and a prolonged period of time (e.g., 10 years) to obtain a statistically robust sample (Wallus, 1983). Without appropriate field effort, lack of documentation here does not necessarily indicate lack of occurrence.

"Mobley's proposed activities in the exclusion zone are not likely to have significant adverse impact on the continuation of the species...There is limited potential for far afield adverse impacts to the paddlefish or other fish species...in fact, the paddlefish population (the best in the state) has been maintained in conjunction with Mobley's historical dredging activities since 1934."

Dredging will threaten the White River population of paddlefish, not the species, therefore "continuation of the species" is not an issue. Variability in habitats among populations indicate the need for managing paddlefish at local, not global levels. Genetic studies of the species also emphasize the need for conservation at local levels, specifically protection of individuals and populations and preservation of migration routes and spawning grounds (Epifanio et al., 1996). Mining of stream substrates, in fact, can degrade aquatic environments and impact communities several kilometers downstream of dredging sites (e.g., Brown et al., 1998). Other than highly speculative and anecdotal observations, there are no data indicating that Mobley's dredging has not impacted paddlefish populations in the White River. This would require demographic data collected prior to 1934 (and none has been presented). It is unclear in what way the White River population is "the best in the state," but the only available field study of White River paddlefish indicates that in any given age group, fish are smaller and slimmer than their counterparts in other streams (Filipek, 1990). Slow growth of a famously fast-growing species (Table 1) and low condition of a frequently fat fish (Table 2; also see photographs in Stockard, 1907) do not support the contention that this is an unimpacted population.

"...paddlefish...are not endangered, threatened or candidate species under the Endangered Species Act (ESA)...there is a commercial season on White River paddlefish...the paddlefish is not a "data element" in either Jackson or Independence County."

Federal listing is not a requirement for permit consideration. Paddlefish are listed as "inventory elements" (equivalent to species of special concern) by the Arkansas Natural Heritage Commission meaning they are "sensitive" or of "conservation concern (Cindy Osborne, pers.comm.)." They are listed as "vulnerable" by the American Fisheries Society (Warren et al., 2000). Such classifications by regional entities (e.g., Arkansas) or scientific groups (e.g., American Fisheries Society) may be used when evaluating permit applications. The existence of a commercial season does not indicate an unimpacted population, since commercial fishing removes adult and sub-adult fishes, other factors may impact early life history stages. Paddlefish not appearing as "data elements" for any individual county cannot be construed as meaning that the species is not of special concern there, since a species is listed only if there is a record of it for that county (Cindy Osborne, pers.comm..). Lack of documentation here does not necessarily indicate lack of occurrence.

"...paddlefish may have been collected within the exclusion zone, none of those were found to utilize the area for reproduction."

There have been no field studies conducted of paddlefish reproduction in this section of the White River. Lack of documentation here does not necessarily indicate lack of occurrence. Physical habitat features are conducive for paddlefish spawning.

"....Exclusion zone and area of proposed activity represents a small fraction of habitat available in the 34 mile reach of the White River from Newport to Batesville."

No data on habitat quality (bathymetry, hydraulics, substrate) or extent are provided to support this contention.

GBMc Comments on Paddlefish

The nine pages of comments are principally reiterations of GBMc positions stated in the Conclusions of this or their original report (09 Aug 2000) with some attempt at support from references listed in the WRAP reports. They will not be addressed here. A few comments, however, merit some clarification. Specifically -

p. 4 – "...information does not support the WRAP's authors [sic] interpretation that spawning temperature of 10 ° C and that incubation temperature of 8 ° C are sufficient to support successful [emphasis added] spawning and larval development."

Incorrect. Firstly – The statement referred to the HSI models invoked by GBMc. The statement was: "These models also indicate that 'optimal' temperatures do not have to be continuously 'maintained' to insure successful hatching and survival, only that a temperature range be maintained above some minimal value (e.g., 8 ° C)." Those models (Crance, 1987 – p. 127 – Fig.4) clearly show a narrower range of suitable (HSI > 0.00) temperatures for spawning (approx 10–23 ° C), than for egg incubation (approximately 6-26 ° C), and early larval survival (approximately 7-32 ° C). The "interpretation," here, is logic. If eggs incubate and larvae survive at lower temperatures than at which they were spawned, it is not necessary that minimal spawning temperatures be maintained for successful, albeit if sub-optimal (HSI = 1.00) spawning. The models, not the WRAP author, indicated that paddlefish eggs spawned at 10-12 ° C can suitably incubate at a temperature of 8 ° C.

Secondly - Temporal trends in the onset of fish reproduction follow latitudinal gradients. The reason is that patterns of sunlight and air temperature vary along latitudinal gradients and those are the exogenous factors associated with gonadal maturation, and other endogenous changes associated with reproduction. Paddlefish spawning in the White River has not been directly observed, but an estimate of the onset of the season can be obtained objectively by looking at latitudinal variation in paddlefish spawning seasons. We have compiled information from our files (Table 3) and we invite others to supplement it. There is a clear trend for earlier spawning at lower latitudes: Feb at < 30 ° N (1/1 study), March at 31-38 ° N (10/16 studies), April and May at 41-42 ° N (3/3 studies), and June at > 45 ° N (1/1 study). The White River exclusion zone occurs at 35.6 ° N. There are eight relevant studies conducted within 1.5 ° latitude of this. Of those 8 studies, five indicate a March onset of spawning. Four of these studies provide some kind of data on water temperature, all of which suggest spawning or spawning migrations occur at temperatures of 6-12 ° C. The median temperature for this range would be 9 ° C.

p.7 - "...preliminary indication that the Arkansas and Osage River populations...are sufficiently divergent from the rest of the Mississippi River populations to warrant separate consideration...WRAP is a misinterpretation of the findings of Epifanio et al., 1996...there does not appear to be a distinctive White River paddlefish population nor can there be based on this research because paddlefish from the White River were MIXED [emphasis added} with Arkansas River paddlefish."

Labeling this as a "misinterpretation" is in fact a "misinterpretation." Firstly, specimens in the Epifanio et al. (1996) study were not "MIXED," data from individuals were pooled. Mixing would obscure differences among sites, pooling allows for evaluation of between site differences (which, according to the authors, was biologically insignificant or undetectable). Authors discuss this at length and it seems apparent from the allele frequency data in the paper.

Secondly, the purposes of the study were to determine whether paddlefish constituted a single, randomly breeding population across its extant distribution (which they did not) and to indicate whether populations have restricted gene flow (which they apparently do) at broad geographic/watershed scales. The authors admit that their sample sizes were small making it difficult to definitively identify distinctive populations or clusters of populations at a sufficiently fine scale to be answered definitively here. The possibility, however, of a distinctive White-Arkansas River population is suggested by three lines of evidence: i) high degree of homozygosity (see Epifanio et al., 1996 – Table 2); ii) an unusual mtDNA haplotype (Epifanio et al., Table 7 – 3/73) unique to the region; iii) the occurrence of three rare nuclear alleles (Epifanio et al., Table 2).

Lastly, the conclusion regarding the separate consideration of the White-Arkansas River paddlefish population was not part of a "misinterpretation." It was an informed statement made by the geneticists in the concluding paragraph of their paper: Geographic variation of paddlefish allozymes and mitochondrial DNA, by John Epifanio and co-workers (Epifanio et al., 1996).

Dr. Epifanio recently told us that mtDNA analyses did not include any specimens from the White River proper, but that because the Arkansas and Lower Missouri Rivers (including the White) displayed the BAA genotype, it indicated a divergent set of populations for the region (pers.comm.). He also stated that there is no "a priori reason to believe that the White River populations would be more like the Mississippi River populations than the rest of the Arkansas or Lower Missouri River populations…until more definitive information could be gathered about the patterns of divergence and genetic relatedness could be established, the "needle on the meter" was pointing toward unique populations."

p.8 – "The flow graphs represented the period 1991-1994 (not 1997-2000 as indicated in the WRAP response). The rationale was to provide the latest data record for the Batesville gage for the same length of time as the water temperature data."

Correct – Our mistake. Statement read: "…temperature and hydrographic data are for different time periods (1991-1994 and 1997-2000 respectively)…" but should have read "….hydrographic data and temperature are for different time periods (1991-1994 and 1997-2000 respectively)…" We apologize for any misunderstanding. Original criticisms of the GBMc report, however, regarding the non-comparable time scales for the two types of data, the difficulty of determining seasonal trends from a single multiple-year hydrograph, and the subjective exclusion of 1987-1990 hydrographs with their elevated discharges in March all stand.

p. 9 - "…mortality rates were from population studies in the southern Alabama River…Atchafalaya River…and Lake Ponctohartrain [sic] in Louisiana…there are significant differences between those waterbodies and the White River…author of WRAP Response appears to be making some broad assumptive statements regarding the general biology of the paddlefish without any evidence that they are relevant to the White River population."

Only partly correct - Those waters are different from the White River, and we were making a broad statement about paddlefish biology. However, there is plenty of "evidence" to support us so "assumptive statements" are not the case here. Until the early 1980s, there were virtually no data for paddlefish mortality rates. Since then, data have been surprising and consistent (Table 4). Mortality of adults and subadults is high, ranging from 15-48%. This should be a source of concern since it is documented for a large, long-lived animal with few natural enemies. Although, two estimates of natural mortality (exclusive of fishing) were comparatively low at < 9 % (Boone and Timmons, 1995) and 11% (Rosen et al., 1982); other studies conducted in areas with no fishing or with harvest moratoria are > 25% (Reed et al., 1992; Paukert 1998). Add to this the possibility of high larval mortality from natural or anthropogenic hydraulic variation (Table 4), and the vulnerability of individual paddlefish populations becomes obvious and troubling.

WRAP Response 01-03 [Sensitive Fish Species]: GBMc Conclusions (p.14)

Note – Four collections of fish made in the exclusion zone in October 2000 documented 30 species of fish (Table 5). Three of these are inventory elements for the state of Arkansas: pealip shorthead redhorse, western sand darter, crystal darter. One is proposed for listing as an inventory element: stargazing darter.

"None of the species...are federally listed T & E species or even candidates for listing."

Federal listing is not a pre-requisite for imposing restrictions on dredging, but "best available information" is. The "best available information" indicates that all five species are imperiled at a regional or national level and warrant some level of protection. Four of the five species are listed by the Arkansas Natural Heritage Commission as "inventory elements" equivalent to "special concern" status; the fifth is under review. Three of the five species are listed as "vulnerable" by the American Fisheries Society (Warren et al., 2000).

"...displacement will be confined to the immediate vicinity of operations with limited far-field effects."

No information is provided that would support this statement. Aquatic habitats, invertebrates, and fishes can be altered over distances of kilometers upstream and downstream of mining sites (Brown et al., 1998). Changes in stream morphometry (geomorphology) of the altered gravel bar could persist for years, possibly decades.

"Each of the species...have established populations in other streams in Arkansas...Mobley's activities will have no effect on the populations present in those streams. "

Impacts to a species are relative (based on the number and distribution of populations), but impacts to a population are absolute. Mobley's activities pose potential impacts to the White River populations.

"The potential impact that the proposed activity would have on the continuance of each of the "species of special concern" is negligible..."

See above. Impacts on the "continuance of the species" are not an issue; impacts on populations are.

GBMc Comments on Sensitive Species

p. 12-13 - Each of the five species accounts written by GBMc documents geographic distribution outside the White River, notes that activities will be confined to the White River, and concludes with a statement to the effect that potential impact of the proposed activity on the continuance of the species is negligible due to limited activities in the exclusion zone, and presence of established populations elsewhere.

An interesting, but hardly novel concept – relying on <u>other</u> populations (and other people) for the "continuance of the species." It did not work for such widespread and abundant species as the American bison, the passenger pigeon, or the harelip sucker. The five species in question are not sufficiently imperiled to be federally listed, but to write off local populations is not environmentally prudent.

First, some of these species may have moderately broad geographic distributions but they are not broadly distributed throughout the White River system. Impacts that occur to the population will be substantial if those species do not occur commonly outside the exclusion zone. GBMc does not provide data to indicate that any of these species are broadly distributed throughout the White River, but historical data suggest that three species are relatively uncommon in the lower reaches of the White River: Sabine shiner, stargazing darter, and western sand darter. Of these species, the geographic range of the stargazing darter is contained almost entirely within the state of Arkansas and should be of particular concern since populations in other states have been extirpated (Robison and Buchanan, 1988). The pealip shorthead redhorse, although broadly distributed throughout the White River, is also geographically restricted, found only in the White and Arkansas Rivers in Arkansas (and the Red River in Oklahoma).

Records for White River Inventory Elements, Robison and Buchanan 1988.		
Common name, scientific name	Number of Records in Upper White River and Black River Systems	Number of Records in Below the Black River
Paddlefish, *Polyodon spathula*	5	10
Sabine shiner, *Notropis sabinae*	16	1
Pealip shorthead redhorse, *Moxostoma macrolepidotum pisolabrum*	4	4
Western sand darter, *Ammocrypta clara*	10	5
Crystal darter, *Crystallaria asprella*	4	4
Stargazing darter (*Percina uranidea*)	13	1

Secondly – species, even endangered species, are usually managed at the population level. This is done partly to preserve genetic integrity of local populations, partly to account for regional variation in abundance, habitat preferences, etc.. Thirdly – Mobley's activities in the exclusion zone may be "limited," but if they take place nearshore where most small fish species occur (instead of the thalweg), or during the early spring (when some of the species are spawning), or if they substantially alter composition of sediments (required by darters), the White River populations will be impacted.

Summary

All available information from the scientific literature, and from information on the White River, indicate that the special conditions of the permit issued to Mobley Construction are reasonable and justified. Specifically:

i) Paddlefish occur in the exclusion zone, and hydrographic pulses and water temperatures in late winter-spring are comparable to those associated with paddlefish spawning elsewhere thereby justifying the designation of the exclusion zone based on habitat (WRAP #01-02).

ii) Paddlefish populations at the approximate latitude of the exclusion zone begin spawning in March thereby justifying prohibition of dredging during the period Mar-June (Table 1).

iii) Four other benthic species of fishes listed as "inventory elements" or under review for listing as such by the Arkansas Natural Heritage Commission are known to inhabit the exclusion zone, utilize sand and gravel substrates, and three of these spawn in spring, thereby providing additional rationale for special conditions of the permit.

Recommendation

To date, literature review and field data relevant to this permit have been provided by the Arkansas Game and Fish Commission and the US Army Corps of Engineers. Because Mobley Construction seeks to exploit a public resource (i.e., White River) for personal profit and at the risk of impacting five fish populations identified as inventory elements by the state of Arkansas (six, if the Sabine shiner occurs in the exclusion zone), it should be incumbent on Mobley Construction to provide additional information to address concerns and prompt re-consideration of the special conditions of that permit.

Mobley and GBMc contend that since there are no empirical data showing that paddlefish spawn in the exclusion zone, and since suitable habitat is available elsewhere, that paddlefish and the other species are just as likely to spawn in other locations (e.g., in the Black River) but offer no supporting data for this contention. Clearly, the only way this issue will be resolved to the satisfaction of all parties is with a rigorous, site-specific, well-designed field study of dredging-related impacts to those fishes and their spawning habitats. We recommend that Mobley Construction fund an independent researcher (or group of researchers) to conduct such a study. Input on the design of such a study should be solicited from and approved by qualified representatives from all affected agencies: CEMVM, ERDC (WES), and AGFC. Scope of study should include immediate and longer-term (1-2 years) effects of mining on water quality, stream hydraulics and geomorphology, substrate composition, paddlefish movements, paddlefish spawning and rearing, occurrence and spawning of other sensitive species

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WRAP RESPONSE # 01-02: Dredging Permit for Mobley Construction Company In the White River, Arkansas: Paddlefish Spawning Habitat in the Exclusion Zone

Background

Mobley Construction Company has requested a dredging permit from the US Army Engineer Memphis District to mine sand from the White River channel above the mouth of the Black River. Memphis District, however, attached a special condition to the permit that prohibits dredging in a reach extending from Rivermile 259 (at the mouth of the Black River near Jacksonport, Arkansas) to Rivermile 274 (near Oil Trough, Arkansas) during the period March-May. This "exclusion zone" was established for this period to protect spawning and rearing grounds of fishes that reproduce in swift water habitats early in the fish reproductive season. Conspicuous among these fishes is the paddlefish (*Polyodon spathula*). The paddlefish is listed as an inventory element (= special concern) by the Arkansas Natural Heritage Commission (Cindy Osborne, pers.comm.), as imperiled (endangered, threatened or special concern) by resource agencies in multiple states (Schmidt, 1996), and as "vulnerable" by the American Fisheries Society (Warren et al., 2000).

Large specimens of paddlefish were first reported in the White River over a century ago (Meek, 1894). Recently, there was a commercial fishery for roe (caviar) and currently White River paddlefish constitute one of only three large populations in the state of Arkansas (Robison and Buchanan, 1988). Paddlefish spawning areas are rarely delineated (Wallus, 1986), but environmental requirements for successful spawning are well-established (Crance, 1987). Requirements include: i) late winter or early spring rise in river stage coinciding with rising water temperatures $\geq 10\,^{\circ}C$; ii) coarse substrate; iii) moderate water depth. Mobley Construction Company and its consultant GBMc and Associates (GBMc) contend that these requirements are either not met in the exclusion zone, or, if met, are not distinctive to the exclusion zone. Mobley Construction Company requests "relief" from the special condition of the permit and maintains that by preventing it from dredging in the exclusion zone during the period Mar-May, the Memphis District is imposing economic hardship to the company.

On 19 Sep 00, a meeting was held among representatives from Mobley Construction Company, GBMc, Memphis District (CEMVM), and the US Army Engineer Research and Development Center at Waterways Experiment Station (CEWES). Attendees were Bryce Mobley and Phyllis Hardin (Mobley Construction Company), Roland McDaniel (GBMc), Judy O. DeLoach, Patricia Jones, Linda Boyd, Larry Watson, and Colonel Kreuger (CEMVM), and Jan Jeffrey Hoover (CEWES). Purpose of the meeting was to summarize and discuss findings of a report by GBMc on suitability of the exclusion zone as paddlefish spawning and rearing habitat.

GBMc concludes that "there is [sic] no data to support the presence of spawning activity upstream of the mouth of the Black River." Because paddlefish population data do not exist for this area, the general approach of the report is valid (i.e., review of data for specific physical factors known to influence paddlefish spawning), but the scope and methodology of "analysis" are flawed. subjective.

Habitat Assessment Criteria Addressed by the GBMc Report

The GBMc report considers several requirements associated with successful reproduction of paddlefish and then dismisses each. Each requirement is listed below along with contrasting opinions of GBMc and CEWES, and supporting rationale for the latter.

Water temperature – Report contends that appropriate water temperatures are not met in the White River. GBMc states that a minimal water temperature of 10 °C is required but that "actual spawning has been reported at 14 °C and most literature indicates the optimum temperature as 16-17 °C." GBMc presents water temperature data for 1997-2000 and concludes "optimum" water temperatures (14 – 17 °C) are not maintained until early to mid- April. Statement assumes that pre-spawning activities (i.e., staging) and spawning at cooler temperatures, which take place early in the season, are insignificant or non-existant, and that temperatures within this optimal range must be maintained for successful reproduction.

These assumptions conflict with field data and consensus of expert opinion. Pre-spawning, spawning, and successful incubation are documented for water temperatures < 13 °C, and/or prior to April, in Louisiana (Alexander, 1915), Tennessee (Pasch et al., 1980; Wallus, 1986), and Iowa (Southall and Hubert, 1984). Models derived from analyses of expert opinion indicate much broader ranges of optimal temperatures for spawning, incubation, and larval development, with lower values (<< 14 °C) providing functional or even optimal temperature for incubation and development (Crance, 1987). These models also indicate that "optimal" temperatures do not have to be continuously "maintained" to insure successful hatching and survival, only that a temperature range be maintained above some minimal value (e.g., 8 °C). Temperature data presented by GBMc indicate that "optimal" temperatures > 14 °C occurred sometime during the month of March or in late February in all four years, and that minimal functional temperatures for spawning ≥ 10 °C and for incubation > 8 °C occurred during most of March during each of the years. During one of the four years, "optimum" water temperatures were attained on 01 Mar, and near-optimum temperatures (12-17 °C) maintained during the entire month. Data indicate then that water temperature in the exclusion zone during March was suitable for reproduction during four out of four years, and "optimal" during one of those years.

Increased sustained flows - Report contends that because of flood control reservoirs upstream from the exclusion zone, spring flows are of insufficient magnitude and duration to support spawning. GBMc supports this contention with a 4 year-hydrograph for Batesville gage during the period 1991-1994. Assumption is that peak flows must be sustained for paddlefish to move into spawning grounds.

This assumption conflicts with established patterns of paddlefish movement and with hydrographic data for the White River. Paddlefish can move upstream incrementally, downstream into pools during falling water and then back upstream when water rises again (Russell, 1986). Paddlefish are capable of multiple spawns within a season and incubation is typically completed in less than 14 days (Purkett, 1961; Wallus, 1986; Yeager and Wallus, 1990). Almost two weeks are required at lower temperatures (10-14 °C) but less than 7 days are required at higher temperatures (15-21 °C). In the White River, individual paddlefish may occupy a short reach of river (e.g., < 5 river miles) for long periods of time before making substantial movements upstream and downstream (Filipek, 1990). Hence, a sufficient net increase in river stage (= discharge) during the spawning period will permit a net upstream movement of fish into favorable habitats if they are available, and if base discharge is maintained for a period of at least two weeks, then incubation will be completed. Paddlefish reproduction is documented for discharges of 10,000 - > 24,000 cfs (Russell, 1986) with greater reproduction occurring at higher discharges (Wallus, 1986).

Data for the Batesville gage during the 1987-1994 period of record indicate that conditions for successful reproduction occur during all but two years. Discharges were greater than 10,000 cfs. In 1991, however, the spring rise in water level was late (after 20 Mar); in 1992 elevated water levels were of very brief duration (10 days). During six of the eight years, however, base discharge (i.e., exclusive of peak flow) in late February and early March increased 1.6 – 2.5 times over that of winter lows and these discharges were maintained or exceeded for periods of 15-60 days. These data are available at: http://waterdata.usgs.gov/nwis.

Substrate – Report concedes (p. 4) that "substrate preferred for spawning activities probably occurs within the exclusion area." CEWES concurs. We know from direct observation that the coarse substrates preferred by spawning paddlefish are widespread in the exclusion zone (pers. obs.).

Water depth - Report indicates that optimal depth for spawning is 4 m (p. 1) and concedes (p. 4) that "there are sections with sufficient depth in the exclusion area." Consensus among paddlefish biologists is that there is a range of optimal depth for larval development of 2-5 m (Crance, 1987). We know from direct observations of channel morphology at low stages that preferred depths are available during higher stages in the exclusion zone.

Spawning data – GBMc reports that in 1989-1990 the Arkansas Game and Fish Commission (AGFC) tagged and released 360 fish, of which 29 were equipped with telemetry devices, and with the exception of a single fish recorded at RM 260, "there is no other definitive information to indicate Paddlefish [sic] use the area of the White River as a spawning area (p. 3)." Statement implies that a large number of fish were available to document spawning activity in the exclusion zone if it occurred there. The information on sampling effort is misleading, and in some cases incorrect.

According to the AGFC report, 360 fish were netted, but only 230 fish were equipped with external tags (Filipek, 1990). Of these, only about 10% were recovered (Steve Filipek, pers.comm.). Given the extent of the river involved (over 150 river miles), the likelihood that any of these individuals would occur in the exclusion zone during the spawning period and would then be recovered is low.

According to the AGFC report, 29 fish were equipped with telemetry devices, but 8 of these (captured in 1988) were difficult to track due to attenuation of signals (in fish with internal antennae) and data in the report were presented only for 20 fish captured in 1989-1990 (Filipek, 1990). Of these 20, only 8 were collected within 60 rivermiles of the exclusion zone. Three of these were collected near RM 200-201, but two of these were subsequently re-captured downstream shortly afterward and prior to being tracked. This left only six fish available for observation. Five of these were collected between RM 250-257: four were captured and tagged in late March 1989 after water levels had already risen, one was captured in mid-March 1990 nearly four weeks after river discharge doubled from 10,000 cfs to > 20,000 cfs. If these fish were going to migrate upstream in response to rising water, then they should have already done so.

In conclusion, only eight fish were tagged within 60 miles of the lower limit of the exclusion zone and all fish were tagged prior to the onset of spring rise in water levels. Only a subset of adult paddlefish spawn in any given year and these make spawning migrations with the onset of rising water levels. The likelihood of tracking one of these fish into the exclusion zone was low because few, if any fish, were available to migrate there.

Stocking program – GBMc states that the fact that AGFC does not stock paddlefish in the White River "indicates that a healthy reproducing population is present (p. 5)." This is incorrect. Lack of stocking does not indicate that a population needs no protection. AGFC reports that fish are not stocked in the White River because the agency does not want to stock less hardy (i.e., hatchery-reared) fish into an existing population of paddlefish (S. Filipek, pers.comm). This also preserves genetic integrity of individual paddlefish populations which have only recently been demonstrated to be genetically variable and possibly distinctive from each other (Epifanio et al., 1996).

Issues Not Addressed in GBMc Report

In addition to the criteria discussed in the GBMc report, other issues are not addressed which are relevant to fish reproduction in the exclusion zone. These include:

Dredging effects on larval paddlefish – Paddlefish larvae exhibit positive rheotaxis (Adams et al., 1999) and low mortality at comparatively high velocities (e.g., 1.5 m/s) so they may resist entrainment in some swift water habitats (Payne et al., 1990). Paddlefish larvae, however, swim from bottom to surface and glide back to the bottom (Wallus, 1986). This could make larvae susceptible to non-lethal entrainment (and loss). Larvae might also be impacted by turbulence generated by some forms of dredge disposal (Killgore et al., 1987). Direct effects of dredging on paddlefish larvae are ignored.

Changes in substrate composition – Paddlefish adults require coarse substrates for spawning (Crance, 1987) and larvae are known to occur over packed sand (Yeager and Wallus, 1990). Dredging will change substrate composition and distribution within the channel. How this will affect quality and extent of paddlefish spawning grounds is not discussed.

Other sensitive fish species - The special condition of the permit restricting dredging in the exclusion zone is not specific to paddlefish. Other sensitive species inhabit this area of the White River that spawn early in the season (March) and/or require large substrates in which to spawn (gravel, coarse erosional sand). These include: Sabine shiner, western sand darter, crystal darter, and stargazing darter. Impacts of dredging on these species are not addressed. At the 19 Sep 00 meeting, GBMc stated that those species were unlikely to occur in the exclusion zone, that the

White River had been extensively sampled, and there were no records for those species in the exclusion zone. Photocopies of distribution maps from the book "Fishes of Arkansas (Robison and Buchanan, 1988)" were distributed to support this contention. CEWES noted that some sections of the White River were not readily accessible to collectors and that the exclusion zone may not have been sampled adequately to refute or confirm the occurrence of those species. CEWES also noted that three of those species were documented above the exclusion zone in the vicinity of Batesville (Neil Douglas, unpublished data; Robison and Buchanan, 1988), that all species have been documented at or below the mouth of the Black River (in recent surveys by CEWES), and that suitable habitat apparently occurred in between these sites.

Miscellaneous Shortcomings of GBMc Report

1. There is no evidence that primary scientific literature was consulted. The five principal references cited include a USFWS "blue book, " book chapters, and an unpublished report. Several relevant studies of paddlefish reproduction are conspicuously absent (e.g., Purkett, 1961; Pasch et al., 1980, Wallus, 1986; Yeager and Wallus, 1990).

2. Standard citation style is not used. It is impossible to know, for example, the source for the statement that 14 $^{\circ}$ C is optimal for paddlefish spawning.

3. Paddlefish spawning is presumably triggered by concurrent rise in water temperature and river stage, but temperature and hydrographic data presented in report are for two different time periods (1991-1994 and 1997-2000 respectively) and are presented at two vastly different time scales (daily Jan-Dec for period of record and daily Feb-May by year).

4. There is no analysis of data. Report makes generalizations based on inspection of raw data but attempts no quantitative summary of data. Minimally, some univariate analyses should have been provided: e.g., frequency and durations of significant, sustained discharge (value to be objectively determined from literature or stage-duration data). Ideally, bi-variate or multivariate analyses of hydrographic data with or without temperature data should have been attempted to determine what percentage of time favorable conditions prevail during the months of Feb, Mar, Apr, May, and Jun for the period of record.

5. There is an implicit assumption that absence of data (i.e., lack of observations) are equivalent to negative data (e.g., lack of occurrence). For example, the absence of observations of paddlefish in the main channel of the exclusion zone can be directly attributed to several factors including low sampling effort there by AGFC, which concentrated efforts in backwaters, chutes, and downstream reaches (S. Filipek, pers.comm.) and the low number of paddlefish equipped with telemetry devises released nearby (Filipek, 1990).

6. Data are frequently missing, ignored, or mis-cited. For example, hydrographic data are omitted for the years 1987-1990 during which early March discharges were elevated, prolonged, and suitable for paddlefish spawning. Also, presentation of a single multi-year hydrograph obscured small-scale variations in base discharge sufficient for paddlefish incubation (i.e., increases of 2-3 weeks duration). The apparent paucity of paddlefish observations in or near the exclusion zone was exaggerated by the failure to restrict interpretations of telemetry data to only those

fish which could have reasonably moved into the exclusion zone during the spawning season based on time of year, river stage, and longitudinal position in the river. Also, there was no mention in the GBMc report of a sixth paddlefish that occurred near the downstream limit of the exclusion zone (#41.500). Finally, the capture date of a sedentary paddlefish near the downstream limit of the exclusion zone (#41.480) was approximated as mid-March rather than early March.

Conclusions

Spatio–temporal variation in paddlefish responses to environmental cues (e.g., Wallus, 1986) make precise and accurate delineation of spawning and rearing grounds difficult, but based on the criteria established in the GBMc report, the exclusion zone provides suitable spawning habitat. During the period Mar-May of most years, rising water levels in late February or early March coincide with rising water temperature; substrates and depths within the reach are suitable for spawning and rearing.

Conclusions of the GBMc report that regulated water flows from the dams upstream of the exclusion zone render it less suitable for spawning than downstream reaches of the White River and the Black River (p. 5) are not supported by Batesville hydrographic data (see above comments) or by the scientific literature. Previous field studies of paddlefish indicate that discharges 10,000 - 30,000 cfs are suitable for paddlefish reproduction (Russell, 1986), that spawning paddlefish preferentially select a variety of habitats (Southall and Hubert, 1984), with spawning more pervasive (i.e., at a greater number of sites) at higher discharges (Wallus, 1986). Therefore, when peak discharges occur in early March, fish would be just as likely to move into the White River exclusion zone as the Black River or downstream (The differences in water temperature between the exclusion zone and the Black River, discussed in the GBMc report, are so negligible as to be within the range of sampling error and small-scale spatial variability). In fact, the large numbers of paddlefish collected in channel scars and chutes in the exclusion zone (S. Filipek, pers.comm.) indicate that paddlefish occur throughout this reach and would support the contention that paddlefish are spawning in that reach.

Individual paddlefish spawning periods are typically brief, but the range of reported water temperatures is relatively broad and timing can vary substantially. Also, multiple spawnings can take place within a single reproductive period, if multiple hydrographic peaks occur, although a relatively low percentage of females reproduce during any single year. Consequently, it is conservative to assume a wide calendar season for paddlefish reproduction and it is prudent to maintain a wide window (i.e., Mar-May) of prohibited dredging in the exclusion zone of the White River.

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ERDC-WES-EL 30 Nov 00

WRAP RESPONSE # 01-03: Dredging Permit for Mobley Construction Company In the White River, Arkansas: Sensitive Fish Species in the Exclusion Zone

Background

Mobley Construction Company has requested a dredging permit from the US Army Engineer Memphis District to mine sand from the White River channel above the mouth of the Black River. Memphis District, however, attached a special condition to the permit that prohibits dredging in a reach extending from Rivermile 259 (at the mouth of the Black River near Jacksonport, Arkansas) to Rivermile 274 (near Oil Trough, Arkansas) during the period March-May. This "exclusion zone" was established for this period to protect spawning and rearing grounds of environmentally sensitive fishes that reproduce in swift water habitats early in the fish reproductive season. These fishes include the paddlefish (*Polyodon spathula*), addressed in a separate report, and four species of small, littoral fishes.

These species and their conservation status are:

Common name, scientific name	Arkansas Natural Heritage Commission	American Fisheries Society (Warren et al., 2000)
Sabine shiner, *Notropis sabinae*	Inventory element	Currently stable
Western sand darter, *Ammocrypta clara*	Inventory element	Vulnerable
Crystal darter, *Crystallaria asprella*	Inventory element	Vulnerable
Stargazing darter (*Percina uranidea*)	Under review	Vulnerable

The Arkansas Natural Heritage Commission (ANHC) use of "inventory element" is equivalent to "special concern" status of other agencies; the stargazing darter is currently under review for addition to the Arkansas list (Cindy Osborne, ANHC, pers.comm.). The American Fisheries Society designation of "vulnerable" indicates a species or subspecies that may become endangered or threatened by relatively minor disturbances to its habitat or that deserves monitoring of its distribution and abundance in continental waters of the United States to determine its status (Warren et al., 2000)."

On 19 Sep 00, a meeting was held among representatives from Mobley Construction Company and its consultant GBMc and Associates (GBMc), Memphis District (CEMVM), and the US Army Engineer Research and Development Center at Waterways Experiment Station (CEWES). Attendees were Bryce Mobley and Phyllis Hardin (Mobley Construction Company), Roland McDaniel (GBMc), Judy O. DeLoach, Patricia Jones, Linda Boyd, Larry Watson, and Colonel Kreuger (CEMVM), and Jan Jeffrey Hoover (CEWES). Primary purpose of the meeting was to summarize and discuss findings of a report by GBMc on suitability of the exclusion zone as paddlefish spawning and rearing habitat. Secondarily, the suitability of the exclusion zone as habitat for these four other sensitive species was discussed.

GBMc stated that those species were unlikely to occur in the exclusion zone, that the White River had been extensively sampled and there were no records for those species. Photocopies of distribution maps from the book "Fishes of Arkansas (Robison and Buchanan, 1988)" were distributed to support this contention. CEWES noted that some sections of the White River were not readily accessible to collectors and that the exclusion zone may not have been sampled adequately to refute or confirm the occurrence of those species. CEWES also noted that all four species have been collected in the White River downstream from the exclusion zone, between RM 247 and RM 259 (CEWES, unpublished data), and all but the crystal darter have been collected in the White River near Batesville, RM 295 (Neil Douglas, unpublished data; Robison and Buchanan, 1988). This distribution, and the presence of shallow, swiftwater habitat and coarse erosional substrates, would strongly indicate that those species should also occur in the exclusion zone. GBMc and Mobley Construction Company did not accept this possibility and indicated that empirical data were required to confirm occurrence in the exclusion zone and, by that fact, the risk of dredging related impacts to those species.

Approach

A field study was conducted 11-12 Oct 2000 to characterize physical habitats in the exclusion zone and to ascertain presence of the sensitive species identified by the ANHC. Data on physical habitat and fishes were collected from four stations in the exclusion zone, three of which are sites which Mobley Construction Company proposes to dredge: RM 262 (2 mi W of Jacksonport, AR); RM 262.3 (downstream edge of Craven's Chute); RM 269.3 (Hulsey Bend); RM 273.2 (Pleasant Island). Stream width was measured from water's edge to water's edge using a LASER rangefinder. Water velocity and depth were measured at 10 approximately equi-distant points along a cross-sectional transect. Water temperature, specific conductance, dissolved oxygen, and pH were recorded with a Hydrolab multi-parameter water quality probe. Turbidity was measured with a Hach 2100P turbidimeter. Dominant substrates were classified qualitatively and recorded. Fishes were collected using standard effort employed in previous studies of White River fishes by CEWES: 5 hauls with a 8 ft X 20 ft, 3/16 inch mesh seine. Additional fishes were obtained by subsequent non-quantitative seining. All fish were preserved in 10% formalin. In the laboratory, fishes were washed, sorted, enumerated, and identified to species according to Douglas (1974) and Robison and Buchanan (1988).

Habitat and Sensitive Fishes in the White River Exclusion Zone

Physical habitat was similar among sites (Table 1). Water was cool (17 – 19 $^{\circ}$ C), moderately conductive (approximately 340 umhos/cm), well-oxygenated (approximately 12 mg/l), alkaline (approximate pH = 9.2), and clear (< 7 NTU). Maximum velocity was 67-77 cm/s and gravel was the dominant substrate with varying amounts of sand. Stream width was 303-336 ft except at Pleasant Island where it was over 1000 ft.

Table 1. Physical habitat in the White River exclusion zone, 11-12 Oct 2000.

Parameter	RM 262	RM 262.3	RM 269.3	RM 273.2
Water temperature (°C)	18.9	17.8	17.2	17.5
Conductance (umhos/cm)	348	342	339	344
Dissolved oxygen (mg/l)	11.9	12.1	11.9	11.6
PH	9.2	9.2	9.3	9.3
Turbidity (NTU)	4.8	6.4	2.9	3.4
Maximum depth (ft)	6.4	10.7	4.0	5.6
Maximum velocity (cm/s)	77	71	67	76
Stream width (ft)	309	336	303	1110
1 ° and 2 ° substrate	Gravel-sand	Gravel-sand	Gravel-sand	Gravel-sand

Thirty species of fish were collected (Table 2). Fish community was dominated taxonomically by minnows (12 species) and darters (9 species). Community was dominated numerically by three species of shiner characteristic of White River fish assemblages: mimic shiner, *Notropis volucellus,* blacktail shiner, *Cyprinella venusta* , and telescope shiner, *Notropis telescopus*. The Sabine shiner was not collected but is likely to occur based on its previously documented occurrence at RM 257.5 and RM 259 (CEWES unpublished data). Other sensitive fish species were collected at all four sites. Western sand darters were collected at RM 262.3, crystal darters at RM 262 and RM 269.3, and stargazing darters at RM 269.3 and 273.2. Additionally, another species listed as an inventory element by the ANHC was collected: the pealip shorthead redhorse, *Moxostoma macrolepidotum pisolabrum*, at RM 273.2. It may not have been included in the ANHC list of sensitive species for this part of the White River due to the paucity of records for this species in this region (Robison and Buchanan, 1988).

Habitat and Reproduction of Sensitive Fish Species in the White River Exclusion Zone

All five species listed by the ANHC occur over coarse substrates and most are early spawners (Kuehne and Barbour, 1983; Page, 1983; Robison and Buchanan, 1988). In Arkansas, distributions are spotty. The Sabine shiner is a bottom dwelling minnow that occurs over silt-free sand. Spawning commences during high water in early spring; gonads begin to mature in March and spawning begins in early April (Heins, 1981). Like other members of the longnose shiner (*Notropis longirostris*) species group, it is a species associate of the sand darters (*Ammocrypta* spp.)(Hubbs and Walker, 1942, Heins and Clemmer, 1975; Heins et al., 1980; Heins, 1981). The shorthead redhorse is found over gravelly bottoms and begins spawning in late April. The western sand darter inhabits sandy substrates, in which it buries itself. Spawning season is not documented but it is presumed to spawn in June. The crystal darter is also found in sand or in fine gravel. It has a protracted spawning season with peak reproductive activity in February and March (George et al., 1996), but many aspects of its biology are unknown due to the specialized field techniques required to collect it (Katula, 2000). It is vulnerable to habitat alterations such as dredging and numbers are declining over much of its range. Kuehne and Barbour (1983) state: "The crystal darter continues to lose ground in the battle for survival partly due to dredging operations and losses of extensive areas of clean sand." The stargazing darter occurs on gravel bottoms and is intolerant of silt. Reproductive season is unknown. This species has been extirpated in several areas including the lower Wabash River and the states of Indiana and Illinois, so that its range now lies mostly within the state of Arkansas (Robison and Buchanan, 1988; Page and Burr, 1991).

Table 2. Fishes of the White River collected between Jacksonport and Oil Trough, Arkansas, 11-12 Oct, 2000. Numbers represent total number collected in a standard effort (5 hauls with a 20-ft. seine). A "+" indicates a species collected during supplemental sampling. Taxa with an asterisk are listed as species of special concern by the Arkansas Natural Heritage Commission. Those with a double asterisk are under consideration for listing.

Common name, scientific name	Rivermile				
	262	262.3	269.3	273.2	Total
Cyprinidae, minnows and carps					
Campostoma anomalum, central stoneroller	+			1	1
Cyprinella galactura, whitetail shiner	1			1	2
Cyprinella venusta, blacktail shiner	250	44	2	107	403
Erimystax x-punctatus, gravel chub	2			5	7
Hybognathus nuchalis, MS. silvery minnow	34	1			35
Macrhybopsis aestivalis, speckled chub	2	6	4		12
Notropis atherinoides, emerald shiner		2			2
Notropis rubellus, rosyface shiner	2		2	52	62
Notropis telescopus, telescope shiner	63	2	3	94	162
Notropis volucellus, mimic shiner	291	34	5	76	406
Pimephales notatus, bluntnose shiner				2	2
Pimephales vigilax, bullhead minnow	53	36		1	90
Catostomidae, suckers					
Carpiodes carpio, river carpsucker	2				2
Hypentelium nigricans, northern hog sucker	1	1		2	4
Moxostoma erythrurum, golden redhorse	31	11		22	64
Moxostoma macrolepidotum pisolabrum, pealip shorthead redhorse *				1	1
Ictaluridae, catfishes					
Ictalurus punctatus, channel catfish	1				1
Atherinidae, silversides					
Labidesthes sicculus, brook silverside	1				1
Poeciliidae, livebearers					
Gambusia affinis, western mosquitofish	2	1			1
Centrarchidae, sunfishes & black basses					
Micropterus dolomieui, smallmouth bass	1				1
Micropterus punctulatus, spotted bass		+			+

Percidae, darters					
Ammocrypta clara, western sand darter *		9			9
Ammocrypta vivax, scaly sand darter	2				2
Crystallaria asprella, crystal darter *	6		2		8
Etheostoma blennioides, greenside darter				1	1
Etheostoma caeruleum, rainbow darter				4	4
Etheostoma stigmaeum, speckled darter	+	2			2
Percina evides, gilt darter			3	5	8
Percina uranidea, stargazing darter **			11	3	14
Percina vigil, saddleback darter	3	13	6		22
Total number of species	748	168	38	377	1331
Total number of fish	19	14	9	16	30

Conclusions

Four benthic species of fish, occurring in the White River exclusion zone and listed as inventory elements by the ANHC, are dependent on gravel and sand substrates, making them directly vulnerable to dredging operations. Mining gravel-sand substrates from the river bottom would entrain these species, some during their spawning season. Net loss of sand from that reach would constitute habitat losses for all species, but particularly so for sand darters and crystal darters (and Sabine shiners should they occur there).

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RECOMMENDATIONS TO MINIMIZE POTENTIAL IMPACTS TO SEAGRASSES FROM SINGLE-FAMILY RESIDENTIAL DOCK STRUCTURES

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INTRODUCTION

Seagrasses are widely recognized as one of the most productive and valuable habitats in shallow marine environments. Seagrass leaves are a major source of food in coastal ecosystems, either through direct grazing of leaves and epiphytes, detrital pathways, or export to adjacent communities (Zieman and Zieman 1989). They play an important role in nutrient cycling, through the production of detritus and transport of nutrients from the sediments to the water column (Kenworthy et al. 1982). Seagrasses also serve as nursery grounds, providing food and shelter for juveniles of many commercially important fish and shellfish species (Gilmore 1987). In the Pacific Northwest, eelgrass has been designated Essential Fish Habitat (EFH) for groundfish, coastal pelagic species and Pacific salmon. In addition to their importance to the biological community, seagrasses may also alter the physical properties of their environment. Dense stands of grasses function as a current baffle, retarding the flow of water, increasing sedimentation rates, and inhibiting resuspension of organic and inorganic deposits (Kenworthy et al. 1982). Roots and rhizomes of seagrasses form a dense mat which binds sediments and reduces erosion (Zieman and Zieman 1989).

Due to continuing rapid development in the coastal zone, there is a concern that the proliferation of dock structures will negatively impact seagrass meadows. Declines in seagrass coverage could have important consequences for those marine animals that utilize seagrass as habitat. Loss of seagrass cover in areas under and adjacent to docks may result from shading, piling installation, and boat traffic (i.e., prop scarring). Although the area of seagrass loss associated with any individual dock can be relatively small, cumulative impacts and fragmentation of seagrass beds may be significant along highly developed shorelines. For example, n Palm Beach County, Florida, more than 50 acres of seagrasses are estimated to have been negatively impacted due to single family dock structures (Smith and Mezich, draft report 1999). In Puget Sound, substantial losses of eelgrass associated with shoreline development have been documented (Thom and Hallum 1990), although the amount of loss directly attributable to residential docks is unknown. With seagrass populations in decline in many areas, coastal resource managers are interested in the development of consistent, defensible guidelines to reduce additional dock-associated impacts to an already stressed resource.

The amount of available light is one of the most important factors affecting the survival, growth, and depth distribution of seagrasses (Bulthuis 1983; Dennison 1987; Abal et al. 1994; Kenworthy and Fonseca 1996). Although the seagrass response to light reduction has been documented in numerous studies using experimentally manipulated light levels (Bulthuis 1983; Neverauskas 1988; Abal et al. 1994; Gordon et al. 1994; Czerny and Dunton 1995; Fitzpatrick and Kirkman 1995), these experimental studies alone do not provide a basis for the development of guidelines to reduce dock shading impacts. The development and application of regulatory policy to address these impacts has been hindered by a lack of supporting data which directly links changes in seagrass characteristics with levels of light reduction associated with various types of overwater structures. Recent studies have documented the shading effects produced by these structures in Alabama (Shafer 1999), Florida (Molnar et al. 1989, Loflin 1995, Beal and Schmidt 2000), Massachusetts (Burdick and Short 1999), New York (Ludwig et al. 1997; Able et al. 1998) and Washington (Fresh et al. 1995, 2000; Thom and Shreffler 1996, Thom et al. 1997). The results of these studies can be used to provide a scientific basis for the development of guidelines and regulations for dock construction and protection of seagrass resources.

In the Pacific Northwest, there has recently been considerable interest in the effects of overwater structures in the marine environment, motivated largely by concerns related to potential habitat and/or behavioral alterations for Puget Sound chinook salmon and Coastal/Puget Sound bull trout, both federally listed species under the Endangered Species Act (ESA). Nightingale and Simenstad (2001) produced an excellent summary of the types and mechanisms of impacts associated with various types of overwater structures. Much of the research conducted in Puget Sound has been focused on the impacts related to the construction and operation of large ferry terminals (e.g. Thom et al. 1996; Thom and Shreffler 1996; Thom and Echeverria 19??, Blanton et al. 2001). Although some of the results of these studies may also be applicable to small, single-family docks, there are issues of size, scale, and frequency of use that may require separate sets of standards or guidelines for large ferry terminals and residential piers.

This document provides a brief summary of current information on the potential impacts of single-family residential dock structures on the seagrasses, with an emphasis on the issues and seagrass species of importance in the Pacific Northwest. Although potential impacts to marine fauna are recognized as a critical concern, this document will focus on the potential impacts to the seagrasses themselves. The information in this document is organized into two major sections. The first provides background information on the minimum light requirements of seagrasses, and documents the effects of reduced light availability on seagrass biomass and density, growth, and morphology. The second provides suggestions on means to reduce potential impacts to seagrass resources associated with single-family residential docks.

EFFECTS OF REDUCED LIGHT AVAILABILITY ON SEAGRASS RESOURCES

In considering the reduction in ambient light associated with dock structures, there are two sources of light attenuation to consider. The first involves attenuation of light by the water column, which is highly variable over multiple time scales from hourly to seasonal. The second involves shading by the dock structure itself, which is less variable and more predictable. The primary mechanism for the changes in seagrass distribution, shoot density, or biomass associated with overwater structures is the reduction in ambient light caused by shading produced by the structures (Fresh et al. 1995). Therefore, most guidance intended to minimize seagrass impacts associated with docks has focused on various methods to increase light availability in the area beneath these structures. As a result, much of the information provided in this document will be focused on this topic. However, there are other sources of potential impacts to be considered. Prop scouring in association with residential docks was noted by Burdick and Short (1999) and Shafer (1999a). Prop wash, scouring, and the associated increase in turbidity have been noted in studies of large ferry terminals (Thom et al. 1996). Growth of seagrasses around the base of pier pilings may be inhibited by changes in bottom topography or the accumulation of shell and debris (Fresh et al. 1995, Shafer and Lundin 1999). Other potential sources of impacts (not addressed in this document) include chemical contamination from leaching of treated wood products and leakage of petroleum products from moored vessels. See Table 10 (p. 34) in Nightingale and Simenstad (2001) for a summary of the habitat impacts and controlling factors related to overwater structures.

Light Requirements of Seagrasses

As photosynthetic vascular plants, seagrasses utilize light in the range of 400-700 nm (photosynthetically available radiation (PAR)) to supply energy for metabolic processes. Decreased ambient light typically results in lower overall productivity, which is ultimately reflected in lower shoot density and biomass. Predicting the potential impacts of dock shading on seagrass resources requires a knowledge of the minimum light requirements of the seagrass species as well as the nature of the light reduction produced by shading. In general, light requirements for submersed aquatic plants are higher than those of shade-adapted terrestrial plants (Dennison et al. 1993). Light requirements of seagrasses are often expressed as a percentage of light available at the surface. Estimates of the average minimum light requirement for seagrasses range from 4.4% to 29.4% of the light available at the surface (Dennison et al. 1993).

Methods for Estimating Seagrass Minimum Light Requirements

There are two general approaches to estimating the minimum light requirements of seagrasses. The first, known as the 'depth limits' approach, involves establishing the maximum depth of seagrass colonization for a particular area. Seagrasses at this depth are assumed to be existing at or near the minimum threshold light requirement. The amount of available light at that depth may be calculated based on an average value for light attenuation by the water column (Kenworthy and Fonseca 1996). An advantage of the 'depth-limits' approach is the direct connection it makes between the maximum depth of seagrass colonization and water column light attenuation. This enables managers to make predictions about the changes in seagrass distribution based on measurements of the diffuse attenuation coefficient ((K_d)- an index of the rate of light loss with increasing water depth). This approach has been used in the development of water quality standards and seagrass habitat restoration goals in Chesapeake Bay and other locations along the Atlantic and Gulf coasts (e.g. Kenworthy and Haunert 1991; Dennison et al. 1993). However, even frequent sampling of water column parameters are likely to miss periodic episodes of intense light attenuation which could be important to seagrass survival. Therefore, the actual seagrass depth limits are likely to differ from those predicted on the basis of average water column attenuation values. In addition, the extreme daily tidal fluctuation in water column depths in the Pacific Northwest may make this approach less applicable than in other areas with less tidal variation.

An alternative approach, known as the carbon balance model, involves estimating the minimum amount of light required to maintain a positive carbon balance. The principal advantage of this approach lies in the direct link between light conditions and plant photosynthesis. Two measures of the quality of the light environment are often used under this approach: the integrated irradiance (in moles photons per unit area per unit time), and the daily period of light-saturated irradiance in hours (H_{sat}). The saturation irradiance is the level of light at which the maximum rates of photosynthesis occur. Further increases in light intensity above the saturation point will result in no further increases in photosynthetic rate. H_{sat}, rather than instantaneous PAR, is the most important characteristic of the light environment affecting eelgrass photosynthesis, growth, and biomass (Dennison and Alberte 1986). The daily H_{sat} has been shown to be the best predictor of daily carbon gain in at least one west coast estuary (Zimmerman et al. 1994), and has been linked to the persistence of eelgrass at the lower depth limits (Dennison and Alberte 1982; 1985). The minimum H_{sat} requirement for an eelgrass population near Woods Hole, Massachusetts was estimated to be at least 6-8 hours (Dennison and Alberte 1985). Empirical data to establish the relationship between maximum eelgrass depth limits and H_{sat} for Pacific Northwest populations of eelgrass are lacking; in a recent literature review of the light requirements of eelgrass by Olsen et al. (1996), this was identified as a critical research need.

Simple carbon balance models may be constructed at the level of the leaf, or the whole plant. However, the minimum light requirements of seagrasses should not be predicted based on measurements of leaf tissue alone. This approach will severely underestimate the amount of light required to support the entire plant (Fourquean and Zieman 1991). Whole plant estimates of compensation irradiance for three seagrass species were at least twice as high as those based on measurement of leaf tissue alone (Fourquean and Zieman 1991).

The carbon balance approach is rarely used in a management context because it requires the use of more expensive equipment and the collection of continuous, time-series data. In practice, aspects of both approaches are often used in combination. Estimates of minimum light requirements using the carbon balance approach may be used to validate estimates obtained through the depth-limits approach (e.g. Dennison 1987).

Light requirements of Zostera marina

The light requirements of *Zostera marina* appear to be at the high end of the range for most seagrasses (18.2-29.4% of surface irradiance (Dennison et al. 1993). There is a considerable amount of variability in the estimates of maximum depth limits and minimum light requirements reported from various regions (Table 1). Most research investigating the light requirements of eelgrass has been conducted along the Atlantic coast of the United States (e.g. Dennison 1987; Dennison and Alberte1982, 1985), California (e.g. Backman and Barrilotti 1976; Zimmerman et al. 1994), or northern Europe (e.g. Olesen and Sand-Jensen 1993) where the sun angle, tidal regime, climate, and other environmental factors differ from those in the Pacific Northwest. Because of regional physiological adaptations, the light requirements of Pacific Northwest eelgrass populations may not be typical of those in other areas.

Table 1. Estimated depth limits mean light attenuation coefficients and minimum light requirements for *Zostera marina*. (Source: Dennison et al. 1993).

Location	Max. Depth Limit (m)	Diffuse Attenuation coefficient (K_d) (m^{-1})	Minimal Light Requirement (%)
Denmark	3.7-10.1	0.16-0.36	20.1 $\pm$ 2.1
Denmark	2.0-5.0	0.32-0.92	19.4 $\pm$ 1.3
Denmark	1.5-9.0	0.22-1.21	20.6 $\pm$ 13.0
Woods Hole, MA	6.0	0.28	18.6

Netherlands	2.5	0.49	29.4
Japan	2.0-5.0	0.38-0.49	18.2 ± 4.5

Until recently, published accounts of the light requirements of Pacific Northwest seagrasses were unavailable (Olson et al. 1996). Thom and Shreffler (1996) conducted a series of *in situ* growth measurements and mesocosm chamber experiments designed to determine the minimum light level for Pacific Northwest populations of *Zostera marina*. In the mesocosm experiments, plant mortality was observed when integrated light levels were below 3 M m^{-2} d^{-1} (expressed as number of photons per unit area per unit time) for approximately one week. In the long-term *in situ* growth studies, drastic reductions in growth rates were observed at light levels of 4-5 M m^{-2} d^{-1}. These data suggest a minimum threshold of at least 3 M m^{-2} d^{-1} is necessary for continued growth and survival of eelgrass (Thom and Shreffler 1996).

Seagrass Response to Shading

Changes in Biomass and Density

The ability to survive extended periods of light reduction varies greatly between species. Species with large rhizomes and proportionately large below-ground biomass (e.g. *Thalassia*) may take months to register an appreciable decline (Neverauskas 1988, Tomasko and Dawes 1989, Hall 1991, Czerny and Dunton 1995). Species with intermediate below-ground biomass (e.g. *Heterozostera tasmanica*) may respond over a period of weeks (Backman and Barilotti 1976, Dennison and Alberte 1982, Bulthuis 1983, Dennison and Alberte 1985). Small, shallow-rooted species (e.g. *Halophila*) may experience rapid declines after only a few days of shading (Williams and Dennison 1990). The effects of shading may be more pronounced during the warmer summer months when seagrasses are actively metabolizing and respiratory demands are higher. In a study of *Heterozostera tasmanica*, an Australian seagrass species, Bulthuis (1983) compared the results of various levels of shading initiated both in summer and in winter. For all light levels, the rate of decline in density was much more rapid for treatments initiated in summer than in winter.

Carbohydrate reserves stored in the rhizomes may play a critical role in the survival and regrowth of seagrasses after periods of unfavorable conditions (Olesen and Sand-Jensen 1993;

Rey and Stephens 1996). The depletion of below-ground storage reserves could result in a lower root:shoot ratio for plants existing in a low-light environment. The root:shoot ratio has been interpreted as an indicator of plant health (Dunton 1996). By shifting resource allocation from below-ground to above-ground tissues, eelgrass plants were able to sustain continued growth over a period of several weeks, in spite of severe shading and loss of plant biomass (Olesen and Sand-Jensen 1993). This strategy would enable eelgrass to maintain low growth rates during the winter months, and may also help seagrasses to survive in the shaded conditions under docks.

In the northern Gulf of Mexico, *Halodule wrightii* was able to persist (at reduced density and biomass), under docks shaded at light levels of 19% and 16% surface irradiance, at shallow and deep sites, respectively (Shafer 1999). Seagrasses were not present under docks at light levels less than 14% surface irradiance. These data are in agreement with estimates of *in situ* compensation irradiance levels of 15-18% surface irradiance for meadows in Texas coastal waters (Dunton 1994; Onuf 1994; Czerny and Dunton 1995). Declines in eelgrass (*Zostera marina*) density in California were observed in as little as 18 days following the initiation of shading experiments in which the ambient light was reduced by 63%. After nine months of this treatment, eelgrass shoot density was reduced by 95% (Backman and Barilotti 1976). The density of flowering shoots was also reduced in shaded treatments.

Leaf Production and Growth

Growth rates in seagrasses typically exhibit seasonal patterns, which follow a general trend of increasing growth rates with increasing solar insolation during the spring and early summer, but these patterns may also be highly correlated with other environmental factors, such as water temperature, day length, etc. Zimmerman et al. (1989) suggest that seasonal patterns in *Z. marina* growth and net photosynthesis may be largely controlled by changes in water temperature. Therefore, any differences in growth as a result of shading may be difficult to detect. This may explain the similarity in growth rates between shaded and unshaded plants reported by both Bulthuis (1983) and Czerny and Dunton (1995).

In the Pacific Northwest, Thom and Shreffler (1996) also observed strong seasonal patterns in eelgrass growth. Maximum *in situ* growth rates occurred at PAR levels of 3-5 M m^{-2}

d^{-1}, although high growth rates were also observed at very low PAR levels. These results may provide further support for the influence of factors other than light on eelgrass seasonal growth patterns.

Other studies have reported dramatic declines in growth rates due to shading (Gordon et al. 1994, Fitzpatrick and Kirkman 1995). The ability to resume normal growth rates following cessation of shading also varied widely by species, and the extent and duration of the shading (Dennison and Alberte 1985, Gordon et al. 1994, Fitzpatrick and Kirkman 1995). Deep water populations of *Zostera marina* responded to light reduction by lowering the rate of leaf production (Dennison and Alberte 1982). Interestingly, leaf production rates in shallow water populations were not similarly affected (Dennison and Alberte 1982).

Because of the influence of factors other than shading on shoot production and leaf elongation rates (Czerny and Dunton 1995), and the ability of seagrasses to maintain growth rates in the presence of severe light limitation through re-allocation of below-ground resources (Olesen and Sand-Jensen 1993), measurement of seagrass growth rates may not be a reliable indicator of light stress.

Plant Morphology

A reduction in ambient light can produce changes in seagrass morphological characteristics such as blade length and width. Depending on the species, blade length has been reported to either increase or decrease in response to shading. *Posidonia sinuosa* leaf length was reported to decrease in response to 80-99% reduction of light (Gordon et al. 1994). Blade width generally remained unaffected. Increases in *Z. marina* leaf length in response to experimental shading were reported by Short (1991). Similar increases were reported for *Heterozostera tasmanica* by Bulthuis (1983), and *Halodule wrightii* (Shafer 1999). This response has been interpreted as an adaptation to increase the amount of leaf surface area available for photosynthesis. Shafer (1999a) suggested that seagrasses in the vicinity of docks may be able to use this mechanism to partially compensate for the reduction in light availability due to shading. Since west coast populations of *Z. marina* are highly morphologically variable (Backman 1991), a similar change in blade morphology in response to dock shading may also occur, but this response has not been documented.

MINIMIZING DOCK-ASSOCIATED IMPACTS

Seagrass Impacts Associated with Boat Moorings

It has been suggested that boat moorings be used in place of piers or docks in order to reduce seagrass impacts associated with these structures. If the moorings could be placed in deep water outside the depth limits of the seagrasses, then this strategy would be highly effective. If the moorings were placed in areas with seagrass, there is the potential for loss of seagrass cover. However, there is very little information which documents the types of seagrass impacts associated with boat moorings. Only two published reports could be found, both from Australia (Walker et al. 1989; Hastings et al. 1995). Results of these studies are presented here in the absence of any comparable information for the Pacific Northwest region.

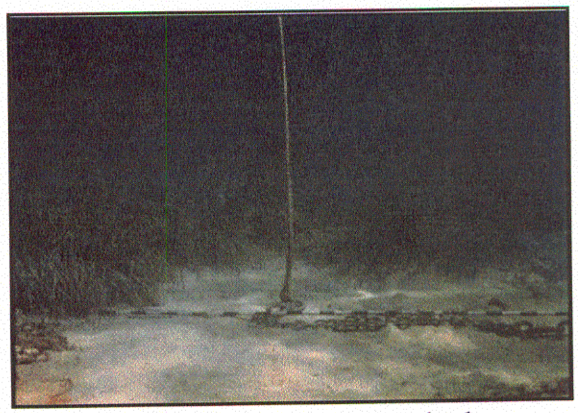

Figure 1. Bare area in seagrass bed produced by mooring chain scour.
Photo source: http://www.q-net.net.au/~amt/enviro.html

Boat moorings can produce circular or semi-circular scoured areas within seagrass beds (Figure 1), ranging in size from 3 to 300 m^2 (Walker et al. 1989). The size of the scours was positively correlated with boat size. In areas with larger tidal ranges (> 1 m), the mooring chains will necessarily be longer, potentially causing more scouring action and damage. The bare areas were generally 0.5 m to 1 m deeper than the surrounding seagrass beds (Walker et al 1989). The accumulation of seagrass detritus within these depressions is believed to be a limiting factor in the subsequent recolonization of the bare areas (Walker et al. 1989).

Figure 2. Area of seagrass loss in a bay with a high mooring density.
Photo source: http:// www.q-net.net.au/~amt/enviro.html

These studies indicate that the area of seagrass loss associated with boat moorings can be significant in some areas (Figure 2). For example, the area of seagrass loss directly attributable to moorings in a bay with a high concentration (344) of moorings was estimated to be 2.45 ha (Walker et al. 1989). In another area, 18% of the total seagrass area was lost due to moorings between 1941 and 1992. Thirteen percent of this loss occurred from 1981 to 1992, coincident with an increase in the number of moorings from 81 in 1977 to more than 190 in 1992 (Hastings et al. 1995). The loss of seagrass was not as dramatic in other bays, however, and seemed to be related to the degree of wave exposure and the sedimentary environment (erosional vs. depositional). Areas with a higher degree of wind and wave exposure and an erosional sediment environment appear to be more susceptible to damage from boat moorings than more protected bays with a depositional sediment environment (Hastings et al. 1995).

Although the area of seagrass loss associated with boat moorings may represent only a small proportion of the total seagrass area, the effect is much greater than if an equivalent contiguous area was lost (Walker et al. 1989). In Rocky Bay, the length of exposed edge increased by more than 250% from 1981 to 1992 (Hastings et al. 1995). Increased fragmentation and loss of bed integrity may make the beds more vulnerable to erosion during storms.

The area of seagrass loss associated with moorings could be reduced through the use of low-impact designs that minimize scouring of the sea floor. Walker et al. (1989) found that cyclone moorings (triple-point) resulted in a smaller area of seagrass loss than swing (single-point) moorings. In response to this finding, the Rottnest Island Authority made a switch from single-chain moorings to 3-chain cyclone moorings. In an investigation of the effectiveness of this measure to reduce seagrass loss, Hastings et al. (1995) observed that in some cases, the cyclone type design resulted in a greater area of seagrass loss than the single-chain design.

Clearly, alternative designs that avoid scouring of the sea floor are needed. An internet search for seagrass-friendly mooring systems turned up a single company, based in Australia, that manufactures and sells a mooring system that claims to result in no impacts to seagrasses. However, the effectiveness of this system to reduce seagrass impacts in the Puget Sound region would need to be demonstrated through an experimental approach.

The area of seagrass in the Pacific Northwest that may be subject to potential damage from anchored mooring buoys is unknown. Aerial surveys combined with GIS analysis could be used to assess the extent of the impacted areas. Studies are needed in order to evaluate the impacts associated with various types of mooring systems in order to determine which system(s) will result in the least impacts to seagrass resources.

Minimizing Seagrass Impacts Due to Residential Dock Structures

Any overwater structure, however small, is likely to alter the marine environment in some way that could potentially affect seagrass resources and their associated fauna. The only way to avoid any impacts to eelgrass resources is to avoid placing these structures where eelgrass is present. However, since this is not likely to be an acceptable alternative, resource mangers need to focus on the development of some reasonable guidelines for the construction of docks and piers which will result in the least impacts to seagrass resources.

The primary mechanism of impact to seagrass resources appears to be reduction in ambient light or shading produced by the structure itself (Fresh et al. 1995). This translates into a reduction in seagrass density or biomass in the area beneath the docks, or in severe cases, a complete loss of all seagrass cover (Fresh et al. 1995; 2002, Burdick and Short 1999). The fragmentation and loss of the physical integrity of the bed that results from complete elimination of seagrass may ultimately affect an area much larger than the original impact. Exposed edges of seagrass patches may be more vulnerable to erosion; these bare areas within seagrass beds may enlarge and 'migrate' across the bed (Patriquin 1975). Walker et al. (1989) also found that the bare patches produced by mooring chains may enlarge and become deeper than the surrounding sediments, limiting the ability of seagrasses to re-colonize the cleared areas. Although some reduction in seagrass density and/or biomass may be an unavoidable consequence of the placement of any dock or pier, complete loss of seagrass cover may be avoided in many cases through careful design and placement of the structures. This will reduce patchiness and fragmentation, and contribute to maintaining the physical integrity of the seagrass beds. If seagrass shoot density is reduced, but not eliminated, some evidence suggests that the individual shoots may be able to compensate in part by increasing blade length or width (Shafer 1999).

Based on the information currently available, some general guidelines are suggested to avoid or minimize seagrass impacts resulting from the construction of residential docks, piers, and floats. As previously noted, there are issues of size, scale, and frequency of use that may require separate sets of standards or guidelines for large ferry terminals and residential piers. The following recommendations are based on a limited number of observations and may require modification when results of on-going and future studies become available. Unfortunately, our current level of understanding does not allow us to make detailed recommendations or site-specific predictions concerning the potential effects of various alternative dock designs. Fresh et al. (2002) recommend that future studies in the Pacific Northwest focus on how the use of open grid deck surface and float orientation and seasonality interact to influence seagrass survival.

Recommendations for Design and Construction of Residential Docks

Avoidance. The placement and alignment of the dock/pier should be designed to avoid areas with seagrass cover to the extent possible. In some situations, the length of the walkway portion of the pier may be increased so that the terminal platform or float is placed over water depths which are too deep to support the growth of seagrasses, as recommended by the Dade County, Florida Department of Environmental Resources (Molnar et al. 1989). Exceptions may be needed in those cases where this may result in an obstruction to navigation. If avoidance is not possible, impacts to seagrasses may be minimized by adopting the design principles suggested in the following sections.

Reduce cumulative impacts. In order to reduce the cumulative impacts associated with the placement of docks and piers, incentives could be used to encourage property owners to build shared facilities rather than multiple individual docks.

Orientation. The orientation of the structure has been noted in several studies as an important factor affecting the survival and density of seagrass. Docks/piers oriented in a north-south direction will produce less shading than those oriented in an east-west direction (Burdick and Short 1999; Shafer 1999; Fresh et al. 2002). Therefore, all overwater structures should be oriented in a north-south direction to the extent possible allowed by shoreline configuration.

Pier Width. The width of the dock or pier should be as narrow as possible without jeopardizing user safety. A maximum width of 4 ft for the walkway portion of the dock was adopted as part of the Florida regulatory guidelines for dock construction in areas where seagrass was potentially affected (Shafer and Lundin 1999).

Fixed Docks. Elevated fixed piers will allow greater light penetration to the underlying seagrasses than floating platforms. Therefore, elevated fixed structures should be used in preference to floating docks whenever possible. Burdick and Short (1999) reported height above the bottom was the single most important factor affecting seagrass bed quality. In Florida, seagrasses were able to persist under docks elevated 4 ft above MHW with a north-south orientation, although biomass and density were reduced by 40-60% (Shafer 1999). Current regulatory guidelines in use in

Florida require docks to be built at least 5 ft above MHW (Shafer and Lundin 1999).

Floating Docks: In Puget Sound and other regions with large tidal ranges, the use of floating platforms for at least some portion of the structure may be a necessity. Floating platforms are likely to result in a greater reduction in seagrass density than fixed docks of comparable size. In Massachusetts, Burdick and Short (1999) reported a nearly complete loss of eelgrass cover under all floating platforms examined. A survey by WDFW in northern Puget Sound conducted in 1989-1990 found that seagrass was completely eliminated under three of the seven non-grated floats examined, and greatly reduced under the remaining four floats (Dan Pentilla, WDFW, cited in Fresh et al. 2002). In some situations, impacts may be reduced by lengthening the fixed elevated pier so that it extends out to a depth deeper than the maximum depth of seagrass colonization, then attaching a float to the end of the fixed pier.

If the floats are allowed to rest directly on the sediments during low tide events, the physical abrasion of the sediment surface can result in direct removal or damage to seagrasses and other benthic and epi-benthic organisms. The installations of stoppers or other mechanisms to prevent grounding will reduce impacts associated with this type of disturbance.

Float Size and Shape. If a floating dock must be used, the size should be limited to the smallest footprint possible. In Florida, the regulatory guidelines for dock construction limit the size of the terminal platform that may be placed at the end of the pier (Shafer and Lundin 1999). The maximum size of terminal platforms built of grating material is slightly larger than that allowed for wood construction, in order to encourage the use of grid material. For wood structures, the dimensions of the terminal platforms may not exceed 6 ft by 20 ft; the total area is limited to 120 sq ft.

For grid structures, the dimensions of the terminal platforms may not exceed 8 ft by 20 ft; the total area is limited to 160 sq ft. In addition, terminal platforms placed over seagrasses may not be covered.

In areas where boats are to be docked, the Dade County guidelines require a minimum depth of -4 ft MLW at the terminal platform (Molnar et al. 1989). Establishment of a minimum water depth for terminal platform placement helps prevent prop scouring, and will also prevent grounding of floating structures.

Comparatively little attention has been focused on the effects of dock shape on seagrass survival. This was one of the factors examined by Fresh et al. (2002) in a study of grated floats in Puget Sound. For reasons that are not entirely clear, floats built in an "I" shape appeared to result in lesser impacts to seagrass density than floats built in a "T" or "L" shape, perhaps because of the smaller footprint size (Fresh et al. 2002). Further research is needed to elucidate the causal mechanisms behind these observed differences.

Alternative Construction Materials. The use of alternative construction materials to increase the amount of light received by the seagrasses below has been suggested as a mechanism to reduce loss of seagrass due to shading impacts. In a preliminary investigation of alternative decking materials which compared acrylic, acrylic with matting, lexan, aluminum grating and fiberglass grating, the Dade County (Florida) Department of Environmental Resources Management (DERM) concluded that only the fiberglass grating material showed promise (Molnar et al. 1989). DERM recommended that additional studies involving dock construction with fiberglass grating be conducted (Molnar et al. 1989). A recent study demonstrated that the docks elevated 4-5 feet above mean sea level using the fiberglass grate (Figure 3) for the entire dock surface allowed sufficient light penetration for continued seagrass survival under the conditions typical of St. Andrew Bay, Florida (Shafer and Robinson 2001). Based on these results, regulatory guidelines for the construction of docks and piers in seagrass beds recommends of the use of grate materials in Florida.

Figure 3. Light penetration through grated dock surface.

A recent study by Fresh et al. (2002) evaluated the use of grate material for floats in Puget Sound, Washington. Fresh et al. (2002) reported that the grated floats were effective in reducing the impacts to eelgrass when compared to ungrated floats. Even if the entire float surface is composed of an open grate material, however, the solid pontoon floats beneath the gr surface may block up to 50% of the grid surface area. Floats should be designed so that the area of the pontoon represents the smallest footprint possible in order to maximize the area of open space available for light penetration.

Blanton et al. (2001) investigated several alternative means to increase the amount of available light under ferry terminals. These included glass prisms, glass blocks, a Sun Tunnel, metal halide lights, and reflective panels. Preliminary results indicated that all of these materials were effective at increasing light levels. However, these studies were conducted in an experimental darkened chamber, and did not take into account the effect of light attenuation by the water column. Similar studies involving construction of experimental docks in a seagrass environment are needed in order to determine which of these approaches are most likely to provide sufficient light for seagrass survival under *in situ* conditions.

In order to evaluate the effectiveness of the reflective panels, several panels were installed beneath a fixed dock located at the Port of Anacortes. The results indicate this approach was effective at increasing the ambient light levels from 1-3% to 9-11% (Gayaldo et al. 2002). Light levels of 9-11% of surface irradiance are within the range of the minimum thresholds for seagrass survival reported by Dennison et al. (1993). Although the exact location of the area affected by the reflective panels could not be delineated, it is likely that they contributed to the survival of the eelgrass transplants and seedling recolonization (Gayaldo et al. 2002).

The effectiveness of glass prisms to increase light levels beneath fixed piers was investigated in the Lower St. John's River system, Florida, by McKinney et al. (2002). The St. John's River is a low salinity, dark water system colonized by brackish and freshwater species of submerged aquatic vegetation such as *Valisneria americana*. The differences in average light levels beneath docks with prisms and those without prisms were statistically significant, but not large (18 $\mu m\ m^{-2}\ s^{-1}$ vs. 25 $\mu m\ m^{-2}\ s^{-1}$). Nevertheless, preliminary results suggest that the additional light provided by the prisms had a positive effect on percent cover and canopy height. The differences in light levels between docks with prisms and those without were more apparent during the winter months than during the summer.

Piling Spacing. The presence of dock pilings results in potential impacts to seagrasses from both direct and indirect sources. Placement of pilings in seagrass beds results in the direct physical removal of seagrass during dock construction. The accumulation of debris and shell from barnacles, molluscs, and other marine organisms at the base of the pilings may inhibit the ability of seagrasses to recolonize the area surrounding the pilings (Fresh et al. 1995; Shafer and Lundin 1999). The presence of pilings can also alter sediment distribution and bottom topography, creating small depressions that preclude eelgrass growth (Fresh et al. 1995). In addition, shading is produced not only by the surface of the dock, but also by the pilings themselves. Therefore, the number of pilings should be limited to the minimum necessary, and the spacing of the pilings should be as far apart as possible, in order to maintain structural integrity of the pier.

Dock Use: Seasonal vs. Permanent. Docks that are used only on a seasonal basis, and removed from the water for a portion of the year, appear to result in little change in seagrass shoot density. In an investigation of the dock attributes associated with seagrass impacts, Fresh et al. (2002) observed no declines in shoot density (compared to controls) beneath two docks that were removed from the water between October and April. Apparently, removal of the float during this period allows the seagrasses to recover from the light-limited conditions imposed by dock shading during the spring and summer. Because of the small sample size of seasonally removed docks available for the study, additional observations at other seasonally removed docks are needed to verify that these results are typical.

SUMMARY RECOMMENDATIONS

- Encourage the use of shared dock facilities to reduce cumulative impacts.
- Relocate or realign the structure to avoid eelgrass beds.
- Extend the length of the walkway portion of the pier so that the terminal platform/boat mooring is located over water too deep to support eelgrass growth.
- Orient all structures in a north-south direction to the maximum extent possible.
- Use elevated fixed piers at least 4-5 ft. above MHW for the walkway portion, then attach a small float portion at the terminal end.
- Use alternative materials (e.g. grid surface for floats, reflective panels on fixed piers) to increase the amount of light penetration to seagrasses.
- Limit the width of the walkway portion of the pier to 4 ft.
- Limit the maximum size of the terminal platform or float.
- Locate the terminal platform or float in water at least 4 ft deep to avoid grounding and prevent prop scarring.
- Use the minimum number of pilings required for structural integrity.
- Consider seasonal removal of the pier.

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WRAP 02-09

Assessment of Potential Wetland Impacts Due to Proposed Realignment of Virginia Route 17, Southern Chesapeake, Virginia WRAP Request 01-xx

By

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Introduction

In May 2001 the Norfolk District requested assistance from the US Army Engineer Research and Development Center (ERDC) under the Wetlands Regulatory Assistance Program (WRAP) to examine potential wetland impacts resulting from a proposed realignment of Virginia Highway 17 near the boundary of North Carolina and Virginia (Figure 1). In response to the WRAP request, Dr. Ellis J. Clairain, Jr. of the Wetlands and Coastal Ecology Branch in the Environmental Laboratory ERDC and Mr. Carlos Latorre of the Geotechnical and Structures Laboratory, ERDC, conducted a site visit 31 July to 3 August, 2001. During the site visit, Dr. Clairain and Mr. Latorre met with Ms. Alice Allen-Grimes and Mr. Steve Martin of the Norfolk District Regulatory Office. We were provided background information on the project and escorted to the field site. Ms. Allen-Grimes and Mr. Martin provided valuable assistance throughout the week and assisted in data collection. We also met with personnel from the city of Chesapeake and discussed the project.

Objectives

Norfolk District personnel expressed concern about identifying and distinguishing the functions and values provided by the swamp and saturated wetlands in the project area, as well as the ability to compensate for impacts to both. The District further expressed a need to obtain a qualitative impact assessment of the functions/values associated with the proposed Route 17 realignment, particularly three different zones along the proposed highway alignment. The three zones are distributed along the highway alignment from north to south with Zone 1, the northernmost zone, representing the permanently inundated swamp comprising approximately 160 m (525 ft) in length. The middle zone, or Zone 2, is the semi-permanently inundated swamp comprising approximately 100 m (350 ft), and southernmost zone, Zone 3, representing the seasonally saturated forest approximately 770 m (2525 ft) in length. Therefore, the objective of this report is to assess the potential impacts of the proposed Route 17 realignment on wetland resources east of the Dismal Swamp canal (Figure 1). A secondary objective is to discuss potential mitigation necessary to address unavoidable project impacts. To assess impacts, it was also necessary to summarize and interpret information on the geology and hydrology of the wetland.

Description of the Project Area

Location and Extent

The wetland adjacent to and east of the Dismal Swamp canal comprises about 2000 hectares. The study area is located in southern Virginia near the city of Chesapeake. The study area includes a large wetland area that is not currently considered part of the Great Dismal Swamp, but probably was at one time before the Dismal Swamp Canal was constructed (Figure 1).

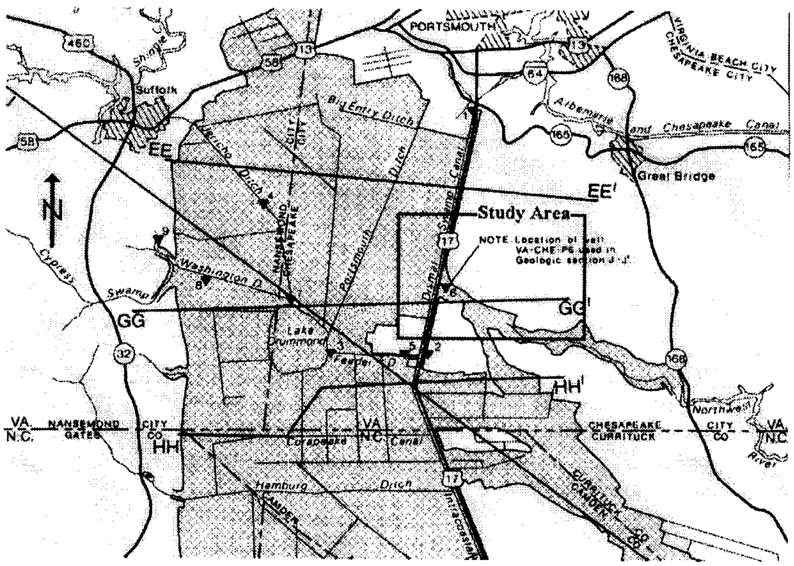

Figure 1. Map of the study area. Shaded areas represent areas sampled in the original publication (after Oaks and Whitehead, 1972).

Regional Topography and Physiography

Morphologic subdivisions in the report are those used by Oaks and Coch (1973, pp 14-24). The surface of the Great Dismal Swamp, west of the study area, slopes gently eastward at about 20 cm per kilometer (1 ft per mile) from an altitude of 7.62 m (25 ft) near the toe of the Suffolk Scarp to 4.57 m (15 ft) near Deep Creek Swale (Oaks and Whitehead, 1972).

Deep Creek Swale bounds the Great Dismal Swamp on the east (Oaks and Whitehead, 1972). The axis of the swale trends north-south, and the land surface rises from the center westward to the Great Dismal Swamp and eastward to the Fentress Rise. The altitude of the swale ranges from about 3.05 m (10 ft) near the center to about 4.57 m (15 ft) near the Swamp and the Fentress Rise.

Climate

The climate of the Great Dismal Swamp area is temperate, characterized by long, humid summers and mild winters. The average annual rainfall at Wallaceton-Lake Drummond station at the control structure on the Feeder Ditch is 128 cm (50.42 in) (U.S. Weather Bureau, 1965). The average annual rainfall is 120 cm (47.19 in) at Suffolk's Lake Kilby and 114 cm (44.94 in) at Norfolk airport. The wettest months at Wallaceton-Lake Drummond station are July and August, with 17 and 15 cm (6.73 and 5.92 in) of rainfall, respectively. The driest months are October and December, with 8.13 and 8.33 cm (3.20 and 3.28 in), respectively.

Average annual temperature is 15° C (59.0 ° F) at Lake Kilby and 15.4° C (59.7 ° F) at Norfolk airport. Temperature is not recorded at Wallaceton-Lake Drummond station.

Geology

Geologic formations underlying the study area range in age from Precambrian to Holocene. Approximately 853 m (2800 ft) of unconsolidated or poorly consolidated sedimentary rocks overlie the crystalline "basement" rocks of Precambrian or Paleozoic age (Fig. 2). The unconsolidated rocks range in age from Late Jurassic and Cretaceous to Holocene. For the purpose of this study, a short review of those formations that underlie the study area and seem particularly relevant to its groundwater hydrology is provided. A brief description of the geologic units that are part of the study area and that are relevant to the surface and subsurface hydrology of the study area are presented in Appendix A.

The thick, rather impervious clay of the Miocene and Pliocene Yorktown Formation, which underlies the entire area, is an effective seal preventing either downward or upward movement of water. The Miocene and Pliocene sediments constitute a confining bed, and water in the underlying Upper Cretaceous is under sufficient head to flow at the land surface. Therefore, if appreciable exchange of water could occur between the Upper Cretaceous aquifers and the Swamp, it would be upward into the Swamp rather than downward to the Upper Cretaceous aquifers.

The geology of the region, as interpreted by Oaks and Coch (1973) shows that the permeable coarse-to medium sand facies of the Norfolk Formation crop out on the Suffolk Scarp and dip under the Great Dismal Swamp. East of the Swamp where the study area is located and under Deep Creek Swale, the Norfolk Formation grades into facies that are much less permeable, and these facies act as a barrier to further eastward movement of water through the Norfolk Formation. The Sand Bridge Formation, which acts as a confining layer, is absent from most of the Swamp area. However, the Sand

Bridge actually overlies the Norfolk Formation except along topographic lows, such as broad stream channels (Oaks and Whitehead, 1972).

Before development of the drainage pattern on the surface of the Sand Bridge Formation (Oaks and Whitehead, 1972), the water in the Norfolk Formation was under artesian pressure caused by recharge in the outcrop area on top of the Suffolk Scarp, but was trapped by the fine-sand facies of the Norfolk Formation to the east and by the overlying silty-clay facies of the Sand Bridge. As downcutting of the broad shallow valleys of the drainage system proceeded, the silty-clay confining layer of the Sand Bridge was removed, thereby allowing upwelling of water from the medium-sand facies of the Norfolk Formation. The addition of this water in an area of poor surface drainage may have been sufficient to trigger the accumulation of peat.

The pre-peat surface is fairly flat (see Oaks and Whitehead, 1972). At a regional level, surface drainage is restricted by the sharp rise of the Suffolk Scarp on the west and by the Fentress Rise on the east. To the north, the flat surface of the Churchland Flat inhibits surface flow, and the flat gradient to the south also inhibits flow. At the study area, ditches that empty into the Dismal Swamp Canal and the Northwest River confine surface drainage. Most surface drainage from the pre-peat surface of the Great Dismal Swamp and the study area was apparently to the east via the ancestral Northwest River, which flowed through a gap in the Fentress Rise, and to the southeast via the Pasquotank River.

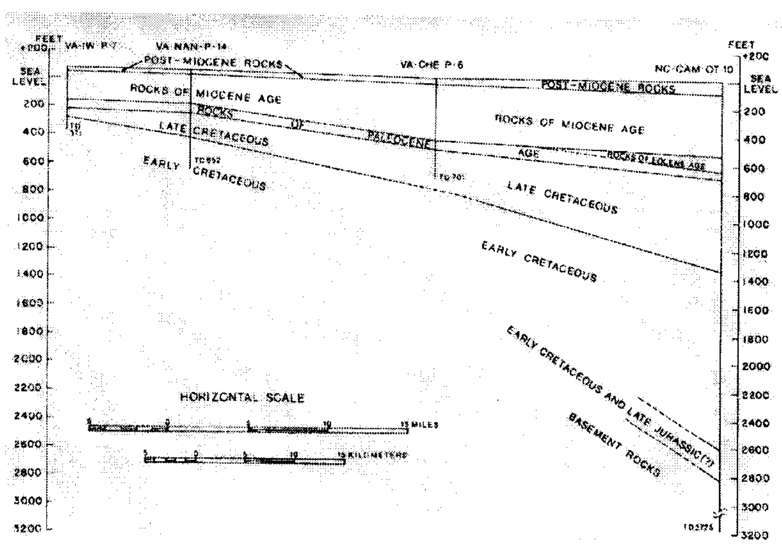

Figure 2. Geologic section showing rock units under the study area (after Brown, et al.1972).

Hydrology and Peat Formation

The hydrology of the Great Dismal Swamp area has been important in the formation of the swamp/wetland in the study area, and will obviously play an important role in its future. The climate, topography, and geology of the area, as previously discussed, are principal factors controlling the hydrology.

The general hydrologic conditions necessary for the formation of the swamp existed in the Great Dismal Swamp area before peat began to form. However, normal dendritic stream drainage patterns were also incised on the Sand Bridge Formation before the peat began to form about 9000 years ago (Oaks and Whitehead, 1972). Studies by Whitehead (1972, p. 301) show that the peat began to form in topographic lows along the stream channels. This, plus the fact that the stream channels had formed, indicates that there was not area-wide ponding in the Great Dismal Swamp when the peat began to form. This fact was observed in the study area.

The groundwater, although a small percentage of the total water budget of the regional area, is especially significant to the study area because the relatively constant quantity keeps the area wet, even during dry periods. Once started, the formation of peat is self-perpetuating. As the peat accumulates, it tends to block stream channels, slow surface drainage, cause local ponding, and hold the upwelling groundwater. The groundwater is distributed by artesian pressure and by capillary action, and the peat gradually spreads to cover the interfluve areas.

Groundwater and Surface-water Relationships. The interrelationships between surface-water and groundwater are basic to an understanding of the hydrology of the study area adjacent to the Great Dismal Swamp. Especially significant is the present hydrologic connection between the Norfolk Formation and the peat.

Groundwater and surface water are more closely interrelated in a swamp than in many other environments. The dividing line is not always clearly defined. Groundwater out of sight below organic litter becomes surface water when the litter is compressed by a footstep. As suggested previously, the formation of the Swamp may have been initiated by seepage of water from the Norfolk Formation. This seepage has probably continued, in modified form, to the present day.

Ditches designed to remove surface water and lower the water table in the peat often intersect underlying aquifers and may deplete groundwater resources if heads in the aquifers are above water levels in the ditches. If heads in the aquifers are below water levels in the ditches, surface water may drain into the aquifers. Rain falling on and near the Swamp may stand on the surface before soaking into the peat and underlying formations. It then moves laterally toward areas of discharge, such as canals or ditches, and becomes surface water again.

Modifications of the Hydrology. Many modifications have been made to the surface-water and groundwater systems of the Swamp. The construction of canals, ditches and dikes to remove excess surface water has made the most change in the hydrology of this area causing a general lowering of the water table. As a result, upland forest assemblages have often replaced swamp vegetation in much of those areas drained by ditches and canals (Levy and Walker). Development of the adjacent former swampland undoubtedly affects the hydrology of the study area, but the effect is probably minimal due to the flat terrain and low permeability of the near-surface material in most of the area. Modification of surface drainage into the Dismal Swamp Canal from the high land to the north, plus the numerous drainage ditches that eventually discharge to Northwest River, undoubtedly have a significant impact. Also, wells near the study area can draw water from the Norfolk aquifer (water-bearing sand in the Norfolk Formation) that underlies the Swamp, reversing the potentiometric gradient and hence the direction of groundwater movement. Groundwater withdrawal from the Norfolk Formation in other areas adjacent to the Swamp may also influence the hydrology.

Surface-Water Inflow. Surface water inflow to the study area originated from west of the Great Dismal Swamp and includes water from Deep Creek Swale. However, these flows are currently cut off by Herring Ditch and the Dismal Swamp Canal. Surface water runoff has also been altered from the north by road crossings at Cornland Road and Douglas Road (primarily at Cornland Road) where ditched and surface water flow is diverted into the Dismal Swamp Canal. A small amount of the runoff from the upland areas is drained into the study area. After examining topographic maps dated 1918 and 1940, we found little evidence of a stream within the study area. However, when we examined aerial photos for the Deep Creek, VA (orthophoto quad 1977, photo revised in 1986), and a map based on photography dated August 2000, there appears to be an old meander scar or standing water where a potentially old river could have occurred.

Groundwater Inflow. Groundwater inflow to the study area and the Great Dismal Swamp is mostly from the west through the Norfolk aquifer and surficial sand that overlies the Sand Bridge confining layer. The flow within the Norfolk aquifer has been modified by withdrawal of water for domestic, stock, and irrigation uses. Ditches that intersect the Norfolk aquifer, can often drain groundwater out of the study area.

Groundwater moving laterally through the surficial sand overlying the confining bed seeps into the peat of the swamp. The movement of water through the peat has not been studied. Most of the peat is sapric (well-decomposed) (Main, Inc., 1971) and has a low hydraulic conductivity below the top few inches. However, desiccation cracks extend 0.46 to 0.60 m (1.5 to 2 ft) below the surface in many parts of the Swamp. The extent of interconnection is fairly good in at least the top 0.3 to 0.46 m (1 to 1.5 ft).

When the water table is at or near the surface of the peat, water probably flows through the interconnected desiccation cracks. As the water table is lowered 0.3 to 0.46 m (1 to 2 ft) below the peat surface, the flow probably decreases drastically. Horizontal groundwater movement through the lower parts of the sapric peat is probably very slow. Except near the ditches, most of the movement is probably in a vertical direction by capillary action.

Groundwater Outflow. Groundwater discharge in the study area is from the Norfolk aquifer and from the peat and muck. Discharge from the Norfolk aquifer is by three routes: (1) by upward seepage through the overlying peat, where the confining beds of the Sand Bridge Formation are permeable or absent, (2) by direct seepage into canals and ditches that intersect the aquifer, and (3) by groundwater pumping near the study area. No direct measurements have been made to estimate the amount of water discharged. Discharge from the peat is by evapotranspiration and by seepage into ditches, canals, and streams. A detailed analysis of the seepage has not been made, but evapotranspiration withdraws are likely to represent discharge of the larger quantity of water from the peat. Pumpage along the study area will increase as areas adjacent to the study area are further developed. In the future, this withdrawal could reverse the gradient in the Norfolk aquifer at least for a portion of the year during the dry season.

Project Description

Most of this short background and project description is derived from the WRAP request provided by the Norfolk District regulatory staff. For several years the Norfolk District has coordinated with the Virginia Department of Transportation (VDOT) concerning their proposed widening of Route 17 in southern Chesapeake, Virginia, ending at the North Carolina state line. As a result of this coordination with the Corps and other agencies, VDOT and the Federal Highway Administration decided to locate the road on a new alignment to minimize impacts to wetlands. The new alignment crosses the paleodrainage of the Northwest River, cut off from its former channel about one kilometer upstream by the construction of the Dismal Swamp Canal (constructed in the early 1800's).

The road, as planned includes a crossing on fill (causeway) of about 760 m (2500 linear ft) across a maple-gum forest community on semi-permanenetly saturated histosols (side slopes), of a width of approximately 61 m (200 ft). The District expects to authorize that fill, with wetland compensation requirements. This seasonally saturated wetland then drops somewhat in elevation into a red maple swamp (permanently inundated) on histosols.

VDOT is proposing bridging approximately one half the width of the swamp. The swamp is approximately 274 m (900 ft) wide, and VDOT's proposed bridge is 122 m (400 ft) long, with the north abutment located on upland at the north end of the swamp. The entire road crossing is approximately 1036 m (3400 ft).

Approach

Prior to conducting a field reconnaissance of the project area, Norfolk District personnel provided the authors with background information, maps and project descriptions for review. During the week of 30 July 2001, we met with District personnel and toured the project area. We also met with personnel from the city of Chesapeake and from the USDA Natural Resources Conservation Service (NRCS). NRCS personnel also provided local expertise on interpretation of hydric soils at the project area and at two potential mitigation sites visited during the week.

After an extensive tour of the perimeter of the project area to get oriented to the site and to ascertain, as much as possible, the surface water inflows and outflows, we identified potential areas for field data collection along the proposed highway alignment and the potential mitigation sites.

A modified version of the Hydrogeomorphic (HGM) Approach to assessing wetland functions was used to conduct the impact analysis. No regional guidebooks are available for the project area in southern Virginia, but a regional guidebook by Ainslie, et al. (1999) was considered the most relevant assessment tool since it is designed to address wetland functions in low gradient, overflow riverine wetlands, like those wetlands in the project area. A plant species list was developed based on expertise provided by Norfolk District personnel and soils information was determined from Mr. Jerry Quisinberry and Greg Hammer, soil scientists from the NRCS field office in Chesapeake.

Field data were collected at three locations along the proposed highway alignment and at each of two potential mitigation sites. All field data forms are provided in Appendix B. Plot 1 was located in Zone 1 approximately at the center point of the proposed 122-m (400-ft) bridge within the old meander scar of the paleochannel of the Northwest River. Plot 2 was located in Zone 2 at the southern end of a potential 274-m (900-ft) bridge. Plot 3 was located in Zone 3 approximately 61 m (200 ft) south of Plot 2 along the alignment. Plot 4 was located on the Cartwright Farm at an area referred to as the Bowl Mitigation Site and Plot 5 was located at the area referred to as the Rattlesnake Mitigation Site, also on the Cartwright Farm. Each plot location was identified using a Garmin XL12 GPS unit and coordinates in UTM are provided in Table 1.

Table 1. Plot locations for data collected at the Route 17 proposed highway alignment and at two potential mitigation sites, Chesapeake, Virginia.

Plot Number	UTM Coordinates		Comments
1	18S0378104	4055065	Center pt of 400-foot bridge in old channel
2	18S0378053	4054846	S end of bridge at 900 ft near stake
3	18S0378021	4054679	S end of transect
4	18S0380024	4052507	Bowl Potential Mitigation Site
5	18S0378970	4053400	Rattlesnake Potential Mitigation Site

Results

Data were collected from each of the three zones within the highway alignment. Data were also collected at the two potential mitigation sites examined. A brief description of each of the five sample areas is provided below. Eight wetland functions are discussed for each of the five sample areas. Functions discussed include the following: Temporarily Store Surface Water, Maintain Characteristic Subsurface Hydrology, Cycle Nutrients, Remove and Sequester Elements and Compounds, Retain Particulates, Export Organic Carbon, Maintain Characteristic Plant Community, and Provide Habitat for Wildlife. Field sheets for all data collected are presented in Appendix B.

Zone 1

Zone 1 is located on the northern end of the proposed highway alignment and encompasses approximately 160 meters (525 ft). This zone represents the permanently inundated swamp. Small meander scars were observed in this zone but very little surface water was present during the site visit. Discussions with Norfolk District personnel indicated, however, that this zone does typically have surface water and that flows do occur during rainfall events. Zone 1 typically floods annually. The plant community is represented by red maple (Acer rubrum), sweetgum (Liquidambar styraciflua), bald cypress (Taxodium distichum), blackgum (Nyssa sylvatica var biflora), swamp cottonwood (Populus heterophyla), and willow oak (Quercus phellos). Soils were organic muck. The water table was found within about 15 cm (6 in.) of the soil surface. As indicated in the previous discussion on the site hydrology, groundwater flows would typically be expected from below with limited lateral flows due to the low conductivity of the organic soils.

Function 1: Temporarily Store Surface Water. Temporarily Store Surface Water is defined as the capacity of a riverine wetland to temporarily store and convey floodwaters that inundate riverine wetlands during overbank flood events. Most of the water that is stored and conveyed originates from an adjacent stream channel. However, other potential sources of water include: (a) precipitation, (b) surface water from adjacent uplands transported to the wetland via surface channels or overland flow, and (c) subsurface water from adjacent uplands transported to the wetland as interflow or shallow groundwater and discharging at the edge or interior of the floodplain. A potential independent, quantitative measure for validating the functional index is the volume of water stored per unit area per unit time (m /ha/time) at a discharge that is equivalent to the average annual peak event. Factors that influence the ability of a wetland to perform this function are overbank flood frequency, floodplain storage volume, floodplain slope, and floodplain roughness.

Zone 1 would effectively provide this function since it is adjacent to a channel and receives overbank flooding each year. Direct observation of this function by District personnel has occurred in the past. Several shallow depressions and channels were also observed during the site visit further enhancing the ability of this zone to perform this function. Considerable therefore, enhancing the ability of this zone to perform this function.

Project conditions would minimally affect this function because the area is to be bridged and the bridge pilings would only slightly reduce the area available for surface water storage. It is also likely that surrounding wetlands would be impacted by the project, because the area is bridged.

Function 2: Maintain Characteristic Subsurface Hydrology. Maintain Characteristic Subsurface Hydrology is defined as the capacity of a riverine wetland to store and convey subsurface water. Potential sources of subsurface water are direct precipitation, interflow (i.e., unsaturated subsurface flow), groundwater (i.e., saturated subsurface flow), and overbank flooding. A potential independent, quantitative measure for validating the functional index is the cumulative number of days in a year that a characteristic depth to water table is maintained. Wetland characteristics that influence this function are soil permability, water table slope, subsurface storage volume, and water table fluctuations.

Zone 1 would effectively provide this function because it is located lowest in the landscape and has organic soils that act as a sponge to absorb surface and groundwater.

The project would only minimally impact this function in neither the footprint or surrounding wetlands for the same reasons as that described for surface water storage.

Function 3: Cycle Nutrients. Cycle Nutrients is defined as the ability of the riverine wetland to convert nutrients from inorganic forms to organic forms and back through a variety of biogeochemical processes such as photosynthesis and microbial decomposition. Potential independent, quantitative measures for validating the functional index include net annual primary productivity (gm/m), annual litter fall (gm/m), or standing stock of living and/or dead biomass (gm/m). Wetland characteristics that influenced this function are tree biomass, understory vegetation biomass, soil O horizon, soil A horizon, and woody debris biomass.

Zone 1 would effectively provide this function because it had a wide variety of plant species in several different strata. The soil characteristics would also enhance the ability of this zone to perform this function.

The project would reduce the ability of this zone to perform this function because it would eliminate all vegetation within the footprint of the project. Soil characteristics would, however, remain unaffected. The surrounding wetlands would only minimally be impacted by the project if vegetation is not altered.

Function 4: Remove and Sequester Elements and Compounds. Removal and Sequestration of Elements and Compounds is defined as the ability of the riverine wetland to permanently remove or temporarily immobilize nutrients, metals, and other elements and compounds that are imported to the riverine wetland from upland sources and via overbank flooding. In a broad sense, elements include macro-nutrients essential to plant growth (nitrogen, phosphorus, and potassium) and other elements such as heavy metals (zinc, chromium, etc.) that can be toxic at high concentrations. Compounds include pesticides and other imported materials. The term "removal" means the permanent loss of elements and compounds from incoming water sources (e.g., deep burial in sediments, loss to the atmosphere), and the term "sequestration" means the hort- or long-term immobilization of elements and compounds. A potential independent, quantitative measure of this function is the quantity of one or more imported elements and compounds removed or sequestered per unit area during a specified period of time (e.g., g/m /yr). Wetland characteristics that influence this function are frequency of overbank flooding, watger table depth, soil clay content, soil redoximorphic features, soil O horizon, soil O horizon, and woody debris biomass.

Zone 1 would effectively perform this function since it floods annually, and has dense vegetation in different strata and soil characteristics suited for effective performance of this function.

The project would significantly affect this function since it would effectively remove all vegetation. Wetlands adjacent to the project are not likely to be significantly affected by the project in Zone 1.

Function 5: Retain Particulates. The Retain Particulates function is the capacity of a wetland to physically remove and retain inorganic and organic particulates (>0.45 microns) from the water column. Retention applies to particulates arising from both onsite and offsite sources. The quantitative measure of this function is the amount of particulates per unit area per unit time (e.g., g/m /yr). Wetland characteristics that influence this function are frequency of flooding, floodplain storage volume, and floodplain roughness.

Zone 1 would effectively perform this function because it floods annually, has a wide floodplain and therefore, considerable floodplain storage capacity, is fairly flat, and has a wide distribution of vegetation which enhances floodplain roughness.

The project will significantly affect this function because it would eliminate floodplain roughness along the highway alignment but surrounding wetlands should not be impacted by the project.

Function 6: Export of Organic Carbon. This function is defined as the capacity of the wetland to export dissolved and particulate organic carbon produced in the riverine wetland. Mechanisms include leaching of litter, flushing, displacement, and erosion. An independent quantitative measure of this function is the mass of carbon exported per unit area per unit time (e.g., g/m /yr). Wetland characteristics that influence this function are frequency of flooding, surface water connections, soil O horizon and woody debris biomass.

Zone 1 would effectively perform this function because it floods annually, is hydrologically connected to the surface water adjacent to the channels, has soils with high organic matter, and considerable woody vegetation generating woody debris.

The project would eliminate the ability of the wetland to perform this function since it would remove all vegetation within the footprint of the project. Although the site would still have the vector (flooding would continue) to export carbon since it is bridged, there would not be the generation of organic carbon to export. The surrounding wetlands, however, would not likely be impacted in this zone.

Function 7: Maintain Characteristic Plant Community. Maintain Characteristic Plant Community is defined as the capacity of a riverine wetland to provide the environment necessary for a characteristic plant community to develop and be maintained. In assessing this function, one must consider both the extant plant community as an indication of current conditions and the physical factors that determine whether or not a characteristic plant community is likely to be maintained in the future. Potential independent, quantitative measures of this function based on vegetation composition/abundance include similarity indices (Ludwig and Reynolds 1988) or 1 ordination axis scores from detrended correspondance analysis or other multivariate technique (Kent and Coker 1995). A potential independent quantitative measure of this function base on both vegetation composition/abundance and environmental factors is ordination axis scores from canonical correlation analysis (ter Braake 1994). Wetland characteristics that influence this function are tree biomass, plant species composition, frequency of flooding, water table depth, and soil integrity.

Zone 1 would effectively perform this function since it had species similar to those expected in similar undisturbed wetland sites and soil characteristics indicative of undisturbed sites.

The project would eliminate virtually all plants within the footprint of the highway and eliminate the ability of the wetland to perform this function within the highway footprint. However, wetlands in Zone 1 adjacent to the project would not likely be impacted by the project.

Function 8: Provide Habitat for Wildlife. The function Provide Habitat for Wildlife reflects the ability of a riverine wetland to support the wildlife species that utilize riverine wetlands during some part of their life cycles. The focus of this model is on avifauna, based on the assumption that, if conditions are appropriate to support the full complement of avian species found in reference standard wetlands, the requirements of other animal groups (e.g., mammals, reptiles, and amphibians) will be met. A potential independent, quantitative measure of this function is a similarity index calculated from species composition and abundance (Odum 1950, Sorenson 1948). Wetland characteristics that influence this function are frequency of flooding, macrotopographic features, species composition, tree biomass, tree density, log biomass, snag density, soil O horizon, wetland tract size, wetland core area, and habitat connections.

Zone 1 had a diversity of plant communities and landscape features to effectively provide this function. It is also located within a large wetland complex, therefore the tract size and core areas are also advantageous for wildlife habitat.

The project would eliminate the plant characteristics and, therefore reduce the ability of the wetland to perform this function, particularly within the footprint of the project. The project would also divide the large, uniform wetland tract into two smaller tracts fragmented by the highway thereby reducing the ability of surrounding wetlands to perform this function as well. Additional vehicular traffic and human disturbance in this zone would also negatively impact wildlife use of adjacent wetlands.

Zone 2

Zone 2 is located south and slightly upslope of Zone 1 along the proposed highway alignment and encompasses approximately 100 m (350 ft). The plant community is dominated by sweetgum and red maple. This area, like Zone 1, also floods annually with several shallow depressions observed near the sample site. The water table at Zone 2 was 30 cm (12 in) below the surface at the time of sampling. The site was underlain with organic soils.

Function 1: Temporarily Store Surface Water. Since this zone floods annually and has several shallow depressions and has dense vegetation which reduces flow velocities, Zone 2 will effectively temporarily store surface water.

The project will eliminate this function within the footprint but have minor impact on lateral surface flows and storage outside the footprint because of the infrequent occurrence of surface water flows at this zone.

Function 2: Maintain Characteristic Subsurface Hydrology. In addition to annual flooding from surface water, Zone 2 is also wetted by groundwater and vertical movement from below as discussed in the hydrology section above. The zone also has organic soils that would perform like a sponge to absorb subsurface water. Therefore, Zone 2 should be very effective at maintaining subsurface hydrology.

The project will eliminate this function within the footprint and could have negative impacts on flood patterns within the project area. Since no bridging is planned for this portion of the project, the causeway will likely cause wetlands to the west (upstream) side of the causeway to become wetter, perhaps killing some trees due to the increased soil moisture and causing a shift in plant composition to more moisture tolerant species. Conversely, wetlands on the east (downstream) side of the causeway will likely become drier. Reduction in flooding on the east side of the project will likely cause a change in plant composition to species more tolerant of drier conditions.

Function 3: Cycle Nutrients. This zone would be effective at cycling nutrients because of the high amount of vegetation and the presence of organic soils.

The project will eliminate this function within the footprint. Wetlands both upstream and downstream of the project will also likely be altered due to changes in the surface and subsurface conditions described above.

Function 4: Remove and Sequester Elements and Compounds. Zone 2 will effectively perform this function because of the frequency of surface flooding and because dense vegetation at this zone will reduce flow velocities causing elements and compounds adsorbed on suspended particulates to settle within the wetland. The high organic soils will also adsorb many elements and compounds.

The project will eliminate this function within the footprint. Those wetland areas on the west side of the project will likely continue to perform this function since flooding will continue and flow velocities will be reduced by the causeway. However, this function will not be performed as effectively as under current conditions on the east side of the causeway because flooding will be reduced as described above.

Function 5: Retain Particulates. Due to annual flooding in Zone 2 and dese vegetation observed at this sample area, Zone 2 would be expected to effectively perform this function. Vegetation will reduce stream velocities, thereby resulting in increased sedimentation and retention of particulates. Other characteristics such as floodplain roughness caused by the shallow depressions and dense vegetation also enhance the ability of the wetland to perform this function.

The project will eliminate this function within the footprint and impede the wetland on the east side of the project to perform this function because flows will not be as accessible to that portion of the wetland.

Function 6: Export of Organic Carbon. To perform this function a wetland must be able to generate organic carbon, as indicated by the plant community and have a vector (flooding) to export it. Although the plant characteristics are present, the transport vector is limited.

The project will eliminate the function within the footprint and impede the ability of adjacent wetlands to perform this function because of project impacts on surface water flow patterns described above.

Function 7: Maintain Characteristic Plant Community. Zone 2 has a diverse plant community but lacks many of the particular species typically found in wetland reference standard sites since this zone does not have similar flooding conditions. Therefore, the site will only partially perform this function.

The project will eliminate this function within the footprint. Plant communities in wetlands adjacent to the project will likely shift from current conditions to wetter species on the west and drier species on the east sides of the project.

Function 8: Provide Habitat for Wildlife. Zone 2 should be very effective at providing this wetland function since it has a wide diversity of plant species and is part of a large wetland tract with a large core area.

The project will eliminate this function within the footprint and fragment the landscape, thereby reducing the ability to perform this function by the surrounding wetlands. Plant communities adjacent to the project would be expected to shift from present conditions to more dry species to the east and wet to the west, as described above. This change in plant composition will likely cause a shift in animal use as well

Zone 3

Zone 3 is located south of Zone 2 in an area less frequently flooded than either Zones 1 or 2. Discussions conducted during field observations in August indicated a flood frequency of about once in 20 years. However, soils in Zone 3 are also high in organic content and described as organic muck. The water table was observed within 30 cm (12 in) of the surface during the site visit. However, saturation was due to groundwater movement from below as discussed in the Hydrology Section above. There was no indication of surface water flooding in Zone 3 during the site visit. The plant community was dominated by red maple and sweetgum in the overstory and poison ivy (*Toxicodendron radicans*), netted chain fern (*Woodwardia areolata*), Virginia chain fern (*W. virginica*), and common greenbrier (*Smilax rotundifolia*) in the understory.

Function 1: Temporarily Store Surface Water. Zone 3 is not likely to perform this function very effectively since the site only floods from surface water about once every 20 years.

Project impacts: little to no impact within the footprint or surrounding landscape

Function 2: Maintain Characteristic Subsurface Hydrology.

Existing conditions: effectively performs this function

Project impacts: likely very little other than in the footprint since groundwater source is primarily vertical from below

Function 3: Cycle Nutrients.

Existing conditions: potentially effect because considerable vegetative cover

Project impacts: complete loss, though little, within the footprint and little effect in surrounding landscape, may see shift in plant community slightly in surrounding landscape but not likely to alter this function

Function 4: Remove and Sequester Elements and Compounds.

Existing conditions: this zone not likely to be very effective at performing this function since infrequently subject to overland flows

Project impacts: little within footprint or surrounding landscape

Function 5: Retain Particulates.

Existing conditions: same as Function 4

Project impacts: same as Function 4

Function 6: Export of Organic Carbon.

Existing conditions: same as Function 4

Project impacts: same as Function 4

Function 7: Maintain Characteristic Plant Community.

Existing conditions: This zone provides a diverse plant community but one not characteristic of wetlands similar to those in Zone 1. Therefore, Zone 3 does not perform this function very effectively.

Project impacts: Those plants within the footprint will be lost and those in the surrounding areas will potential change slightly not be significantly altered by the project.

Function 8: Provide Habitat for Wildlife.

Existing conditions: Zone 3 seems to be important for black bear habitat and as a migration corridor. It would also be useful habitat for a variety of other wildlife species.

Project impacts: The project footprint would provide an obstruction to bear migration patterns. It would also provide a safety hazard for any wildlife that would attempt to cross the highway. Wildlife in the surrounding wetlands would be affectied by the additional noise and human disturbance. The wetlands would also become more fragmented by the project and affect those species that require large areas for various life stages.

Potential Mitigation Site 1 (Bowl)

The potential mitigation site referred to as the Bowl site is located east of the proposed highway alignment approximately 3.5 km (2 miles). It is an active agriculture field with soybeans growing at he site during the site visit. It does not currently flood often but, by plugging nearby ditches, could potentially be subject to annual flooding. Soils are slowly permeable with a seasonally high water table observed about 50 cm (20 in) below the land surface. The site is surrounded on the north by the adjacent wetland floodplain but open active agricultural fields to the south.

Function 1: Temporarily Store Surface Water.

Existing conditions: site only provides minimal storage of surface water since it is the objective of current landuse to grow crops

Potential mitigation functional lift: the site could effectively provide this function if surrounding ditches were plugged and water allowed to remain on the site

Function 2: Maintain Characteristic Subsurface Hydrology.

Existing conditions: the site seemed to have high organic soils so some subsurface hydrology may remain but is limited by the active efforts to remove the surface hydrology

Potential mitigation functional lift: could be improved with reintroduction of surface water hydrology

Function 3: Cycle Nutrients.

Existing conditions: currently does not perform this function since little vegetation on site other than agricultural crops which typically require addition of nutrients to sustain productivity

Potential mitigation functional lift: addition of native vegetation and increase in plant cover would improve the functional capacity of this site to perform this function

Function 4: Remove and Sequester Elements and Compounds.
Existing conditions: site does not currently perform this function since not subject to overland flooding
Potential mitigation functional lift: could gain functional lift and improve functional performance by increasing flooding

Function 5: Retain Particulates.
Existing conditions: site retains particulates generated on site since not readily accessible to adjacent streams but does not retain particulates from surrounding streams
Potential mitigation functional lift: could be improved by reconnecting to adjacent streams

Function 6: Export of Organic Carbon.
Existing conditions: site does not perform this function since not connected to streams
Potential mitigation functional lift: could be improved by reconnecting to adjacent streams

Function 7: Maintain Characteristic Plant Community.
Existing conditions: no plant community characteristic of similar wetlands currently occurs
Potential mitigation functional lift: could be improved considerably by planting native species with diversity of species similar to those expected in floodplain forests

Function 8: Provide Habitat for Wildlife.
Existing conditions: the site provides minimal wildlife habitat because of the limited plant species
Potential mitigation functional lift: could be improved considerably by planting native species but will continue to be constrained somewhat by the surrounding open agricultural land to the south

Potential Mitigation Site 2 (Rattlesnake Field)

The potential mitigation site referred to as the Rattlesnake Field site is also located east of the proposed highway alignment but only about 2.0 km (1 1/4 miles). It is also an active agriculture field but was not planted in any crops at the time the site was visited. Dominant vegetation was barnyard grass (*Echinochola crusgalii*). It does not currently flood often but, by plugging nearby ditches, could potentially be subject to annual flooding. Soils are slowly permeable with a seasonally high water table observed about 194 cm (37 in) below the land surface. The site is surrounded on the north by the adjacent wetland floodplain but open active agricultural fields to the south.

Function 1: Temporarily Store Surface Water.

Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 2: Maintain Characteristic Subsurface Hydrology.
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 3: Cycle Nutrients.
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 4: Remove and Sequester Elements and Compounds.
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 5: Retain Particulates.
Existing conditions:
Project impacts:
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 6: Export of Organic Carbon.
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 7: Maintain Characteristic Plant Community.
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Function 8: Provide Habitat for Wildlife.
Existing conditions: see conditions described for Bowl mitigation site
Potential mitigation functional lift: see Bowl mitigation site

Conclusions

Conclusions are based on limited information, two days of meetings with Federal, State, County and City government, local contractors, and two days of fieldwork.

The hydrology in the study area seems to be driven by a combination of groundwater and slow surface drainage. There is little evidence of large flow volumes of surface water through the study area, except during extreme rainfall events (500 year flood, e.g. Hurricane Floyd). The Department of Public Works (DPW) for the City of Chesapeake computed approximate bridge crossing requirements and determined that, assuming a drainage area of about 200 square miles, and for a Hurricane Floyd level event (about 41-61 cm (16-24 in) of rain in a 24-hour period) would require 38-46 m (125-150 ft) of bridging so the 122 m (400 ft) would be more than adequate for surface flows. Based on field observations and computations made by the DPW for the City of Chesapeake, we believe that the 122-m (400-ft) bridge that the Virginia Department of Transportation (VDOT) proposed to build in the study area is likely to meet or exceed the requirements for appropriate surface flow, including a 500 year flood event.

Instead of a 122 m (400 ft) single bridge, the Norfolk District might suggest creation of a couple of bridges instead, to enhance bear crossings, and allow surface water flows and uninterrupted lateral groundwater flow though the upper 61 cm (2 ft) of the mucky peat. The 122 m (400 ft) bridge will not affect the flow of surface water or groundwater.

A proposed 762 m (2500 ft) causeway will not likely affect surface water flows in the study area because the surface water will flow parallel to the causeway, from high elevation to low elevation. Therefore, shallow culverts through the causeway are not necessary. The causeway could affect the horizontal movement of groundwater in the upper 61 cm (2 ft) of the mucky peat if granular material is not used at the base. Depending on the thickness and hydraulic conductivity of the granular material, the engineered system could further improve the existing lateral groundwater flow in the area.

VDOT has several options to build the causeway. They can remove the mucky peat before the foundation is built, or they can excavate 0.92 to 1.52 m (3 to 5 ft) of the mucky peat and use a geotextile. They have also proposed to excavate in part of the wetland near Zone 2 and use heavy equipment to compress the organic soils in Zone 3. If VDOT chooses to remove the mucky peat before building the foundation, the excavated mucky peat should be taken to use at the mitigation sites and redistributed over the entire area. Peat will provide a useful seed source and further inhibit surface drainage, which in turn can accelerate the accumulation of additional peat until the interfluve areas are covered. If VDOT chooses to excavate 0.92 to 1.52 m (3 to 5 ft) and use a geotextile, it should provide plans and design of construction to Norfolk District staff. The use of geotextile materials can be successful in this area, but the plan needs to specify where the geotextile is going to be anchored. This process requires digging trenches in the ground, setting the geotextile in the trench, and reloading with excavated material, a process that can damage more wetland space than just that directly in the project footprint.

The causeway construction is not likely to obstruct groundwater movement because the direction of groundwater flow is upward (from the aquifer to the surface) as described in the hydrology section. Therefore, the wetlands adjacent to the causeway should not experience subsidence and change in plant community composition due to the changes in groundwater levels caused by the construction of the causeway. Both sides of the causeway (east and west) should have the same hydrologic and geologic conditions. However, in at least parts of the Great Dismal Swamp, roads built on spoilbanks have provided high ground and sunlit areas. Such changes and repeated lumbering have caused a different flora and fauna to develop. If that trend is repeated in the study area during the construction of Route 17, the wetland immediately adjacent to the causeway could become more like an upland forest than it is at present.

Zones 1, 2 and 3 provide many wetland functions but the functional capacity of these zones vary as one moves from the north end of the proposed alignment to the south since the elevation slowly rises in that direction. Flood frequency decreases from annual flooding in Zone 1 to flooding about once every 15 years in Zone 3. This reduction in flooding results in a difference in the functional capacity of these areas and, consequently, differences in plant communities responding to the different flooding regimes.

Although each zone performs wetland functions to different degrees, the project will eliminate all wetland functions within the footprint of the highway alignment. Secondary effects of the project adjacent to the highway alignment are most likely confined to reduction in wildlife habitat quality. The wetland will be fragmented as a consequence of the project and therefore, reduction in wildlife habitat.

Both mitigation sites examined have the potential to address wetland functions lost. Both will require reconnecting to the adjacent stream to increase the flood frequency. Appropriate plant species should be established early so that plant communities can develop. Small trees could also be planted instead of seedlings to reduce the time necessary to get more mature forest communities.

Recommendations

To understand the hydrology of the study area there is a need to develop a hydrologic budget. The study could involve detailed monitoring of precipitation, temperature, evaporation, surface runoff, and ground water levels. A number of test wells may be necessary.

Continuous records of stream or ditch flow for several years are needed to assess surface-water conditions in the study area/swamp adequately, but owing to the short time available, flow data should be obtained during a wet and a dry season.

More detail hydrologic studies needed to provide data to aid in managing the study area include:

1. Defining the present role of the Norfolk aquifer (Scattered borings indicate that some parts of the Swamp remain wet even during droughts because of upward seepage of groundwater; determining the extent and amount of upward seepage is essential.)
2. Determining how withdrawal of water from the Norfolk aquifer has changed groundwater flow patterns and the effect future withdrawal may have on the Swamp
3. Identifying those parts of the study area best suited to wetter types of ecosystems and those best suited to dryer types

4. Determining surface inflow to the study area
5. Determining surface outflow from the study area
6. Determining the number and types of structures necessary to control surface water movement in the study area
7. Determining the water budget of the study area
8. Monitoring seasonal and long-term changes in groundwater elevation and flow direction

Recommend mitigation sites that might include some of the following characteristics:

1. Potential ability to reconnect to a riverine floodplain
2. Flood frequency should be re-established at an annual flood frequency
3. Occur on predominantly organic soils. Establish plant composition similar to those that one would observe at other reference standard sites

Sealing ditches and/or restricting pumping from the Norfolk aquifer can raise water levels in the study area. Data are insufficient at present to predict the hydrologic effect of various possible control measures, but if water levels are abruptly raised too high, many trees will be unable to adapt rapidly and will be killed (Mary Keith Garrett, personal communication).

In conclusion, the three zones in the proposed highway realignment have differing functional capacities, influenced primarily by the differences in flood frequencies and consequently differences in plant composition. The proposed project will eliminate all wetland functions within the footprint. Secondary impacts are expected to occur for wildlife habitat due to habitat fragmentation and increased human disturbances by increased traffic and potential commercial development adjacent to the highway. The two proposed mitigation sites have several positive characteristics that could result in positive wetland enhancement. The organic soils to be excavated from the highway right-of-way should be placed in any mitigation sites to enhance formation of organic peat and to provide a seed source for plant establishment.

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Appendix A

Description of Geologic Units in the study area

Miocene and Pliocene Rocks of the Yorktown Formation

The Yorktown Formation is the uppermost formation of the Miocene Series. Recent studies of vertebrate fossils conducted by the U.S. Geological Survey indicate that the upper part of the Yorktown is of early Pliocene age. The Yorktown Formation extends to within 15.24 m (50 ft) or less of the land surface and is exposed in sand pits, where it can be recognized by its characteristic blue-gray color in unweathered sections and by the yellowish-orange and dark reddish-brown saprolite above the unweathered section.

The upper surface of the Yorktown Formation is an irregular erosional surface that slopes gently eastward from about 34.6 m (130 ft) near Petersburg, Virginia, to below sea level in the Dismal Swamp (Oaks and Whitehead, 1972, Fig. 2). Present-day drainage channels generally follow the old post-Miocene channels.

Pliocene and Pleistocene Formations

Post-Yorktown geology is much more complicated than once supposed, as explained in detail by Oaks and Whitehead (1972). The Norfolk Formation unconformably overlies the Yorktown beneath most of the Dismal Swamp, the southern part of the Deep Creek Swale, and the northern segment of the Fentress Rise (Oaks and Whitehead, 1972). Norfolk sediments are unconformably overlain by the Londonbridge Formation in the Deep Creek Swale, in parts of the Dismal Swamp. Sediments of Holocene age overlie the Norfolk Formation, where other post-Norfolk units are absent (Oaks and Coch 1973). The Norfolk Formation is composed of a lower member and a highly variable upper member. The lower member consists of bluishgray, subangular to subrounded, fine to a very coarse quartz sand containing from a trace to 20 percent fine pebble gravel. The lower member is present through virtually the entire area of the Dismal Swamp and is a useful stratigraphic marker (Oaks and Coch, 1973).

The upper member of the Norfolk Formation consists of eight facies. The coarse-sand facies grades eastward under Dismal Swamp into the medium-sand facies (*Qns*). The medium-sand facies underlies most of the Dismal Swamp and, in turn, grades into the finesand facies (*Qne*) beneath most of the area east of the Dismal Swamp, including the study area (Fig. 3). These facies (*Qns*, and *Qne*) of the Norfolk Formation probably play an important role in the hydrology of the study area.

The Londonbridge Formation occurs in the subsurface beneath most of Deep Creek Swale and the eastern part of the Dismal Swamp (including the study area). The Londonbridge Formation is a clayey silt that unconformably overlies the Norfolk Formation. The Londonbridge Formation underlies the Sand Bridge Formation except along pre-Holocene channels where both formations are missing (Oaks and Whitehead, 1972).

The Sand Bridge Formation is composed of a lower member of homogeneous sand and an upper member that is variable in some areas but fairly homogeneous in the Dismal Swamp. It generally overlies the Londonbridge Formation where present, or unconformably overlies the Norfolk Formation.

The upper member overlaps the lower, so as to overlie the Londonbridge Formation in the southern part of Dismal Swamp and the Norfolk Formation along the western part of Fentress Rise and the western part of Dismal Swamp. Beneath the Swamp and Deep Creek Swale, the upper member of the Sand Bridge Formation is composed of silty clay (Oaks and Coch 1973, p. 94). In most places, the silty clay is very light gray to dark gray, has a blocky, massive texture, and is cohesive.

The Sand Bridge Formation is late Pleistocene in age and is at least as old as mid-Wisconsin. It probably belongs to the same major submergent episode as the Londonbridge Formation. A surface drainage pattern was eroded into the surface of the Sand Bridge or older formations before the emplacement of Holocene deposits (see Oaks and Whitehead, 1972, Fig. 9).

The Holocene in the study area consists of a basal inorganic layer, generally not more than 30.48 cm (1 ft) thick, and the overlying organic peat. The inorganic layer, commonly found only beneath thick peat layers, consists of white, angular, fine to medium sand presumably of fluvial origin. It is overlain by soft, light-blue clay containing organic fragments and freshwater microfossils (Oaks and Coch 1973). The Dismal Swamp Peat is "a soft, wet, sponge-like mass of decaying organic material, chiefly leaves, twigs, rooted stumps and fallen logs" (Oaks and Coch 1973, p. 106). Its color ranges from dark brown near the surface to brownish black at depth. The thickness is highly variable within the Swamp and ranges from a featheredge to more than 12 feet. The surface of the peat slopes gently eastward from an altitude of 25 feet at the base of the Suffolk Scarp to 15 feet along the west side of the Deep Creek Swale. Natural surface drainage is poor, and there are no well-developed streams.

The peat in the study area is entirely of freshwater origin. The oldest radiocarbon age of five specimens of the peat is 8900 ± 160 years B.P. (before present) (Oaks and Coch 1973). Radiocarbon ages of freshwater peat found between 70 and 89 feet below present sea level in the mouth of Chesapeake Bay ranged between 8135 ± 160 and 15,280 ± 200 years B.P. (Harrison et al. 1965). Therefore, the oldest known peat in the study are began forming while sea level was 60 to 70 feet or more below its present level. Sea level probably has not been significantly higher since that time than it is at present.

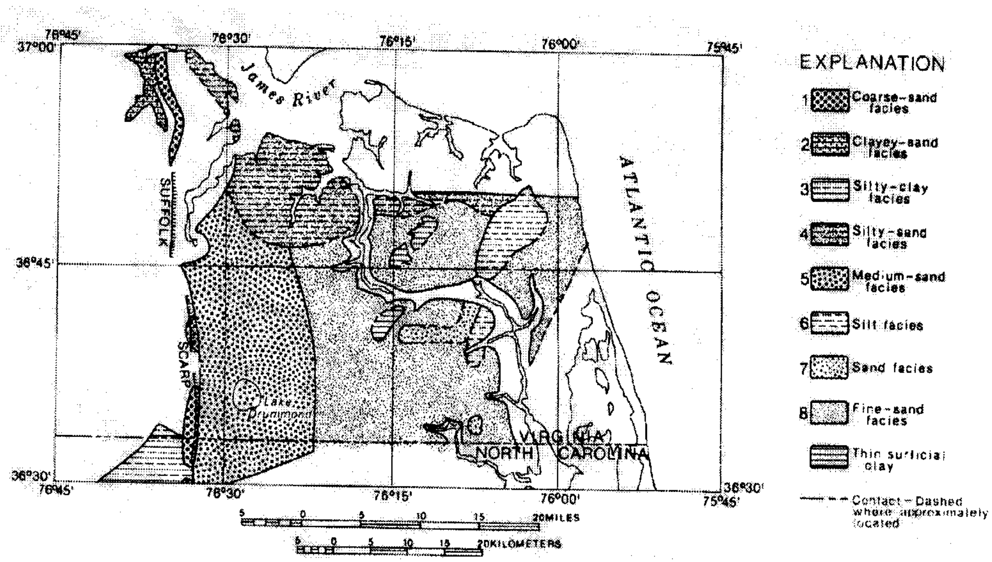

Figure 3. Distribution of major sediments facies of Norfolk Formation, Southeastern Virginia (after Oaks and Coch 1973).